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THE TAXONOMIC SIGNIFICANCE OF BARK STRUCTURE IN SOUTHERN AFRICAN EUPHORBIACEAE

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THE TAXONOMIC SIGNIFICANCE OF BARK STRUCTURE IN SOUTHERN AFRICAN EUPHORBIACEAE

by

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CHAPTER 1

INTRODUCTION

The Euphorbiaceae is one of the largest and taxonomically one of the most complex of flowering plant families in the world. According to Cronquist (1981), the family consists of about 300 genera with 7 500 species. Mabberley (1987) gives 326 genera and 7 750 species. Webster (1987) holds that this family is composed of about 300 genera and about 8 000 species. Meeuse (1990) states that this family comprises possibly 400 genera and approximately 9 000 species.

Arnold & De Wet (1993), recorded 51 genera with 468 species in their *Plants of southern Africa: names and distribution* (covering all countries south of the Kunene and Limpopo Rivers). Palmer & Pitman (1972), documented 29 tree genera with 60 species that are found in South Africa, Namibia, Botswana, Lesotho and Swaziland. Coates Palgrave (1981) listed 37 tree genera consisting of 91 species for southern Africa (region south of the Kunene, Okavango and Zambezi Rivers). In their *National List of Trees*, De Winter, Vahrmeijer & Von Breitenbach (1987), recorded 60 species representing 29 genera that occur in South Africa.

The Euphorbiaceae is also one of the most heterogeneous families of the angiosperms. Its members are highly diversified ecologically as well as morphologically and biochemically (Cronquist 1981, Webster 1987, Meeuse 1990).

The family is cosmopolitan in distribution, though best developed in tropical and subtropical regions. In southern Africa members of the family are widely spread in all types of soils and climate. Many members of this family also thrive well in temperate regions (Palmer & Pitman 1972, Coates Palgrave 1972).

According to habit, members of the Euphorbiaceae may be tall trees, shrubs, lianas, perennial and annual herbs, vines, geophytes, succulents and floating hydrophytes (Webster 1987).

The morphological diversity within the family is exhibited, *inter alia*, by the following features: plants monoecious or dioecious; leaves alternate, opposite or whorled, simple or variously compound with pinnate or palmate venation; flowers small, unisexual, actinomorphic, hypogynous; inflorescences basically racemous, often condensed and giving the appearance of a single flower (cyathium); a receptacular nectary disc may be present or absent; androecium of one stamen to many and often connate, pollen grains binucleate to trinucleate with very diverse exine sculpturing; gynoecium syncarpous, bicarpellate to pentacarpellate with styles undivided to multifid; fruits mostly capsular, but may be drupaceous or otherwise; seeds with two cotyledons, endospermous or exendospermous (Palmer & Pitman 1972, Cronquist 1981, Jones & Luchsinger 1986, Webster 1975, 1987, Mabberley 1987, Meeuse 1990).

The biochemical diversity is expressed, *inter alia*, by many members that produce milky or coloured latex which may be toxic or non-toxic. These secretions are produced in specialised cells, in articulated, non-articulated laticifers or ducts which may be branched or unbranched. Various alkaloids and specialized cells that are often tanniniferous or mucilaginous are also produced by some members. Different types of solitary or clustered crystals of calcium oxalate are encountered in most members of this family. More biochemical diversities are indicated in the compilations of Hegnauer (1966) and Gibbs (1974) and have provided a huge body of information of great systematic interest (Cronquist 1981, Webster 1987).

The classification of the Euphorbiaceae is very controversial. Webster (1987) admits that detailed morphological and anatomical studies are still needed for many genera, because the classification of this family is still unsatisfactory. Recently an attempt has been made in *Annals of Missouri Botanical Garden* 81 (2), 1994, wherein various aspects of the systematics of the Euphorbiaceae are tackled to resolve the controversy in the classification of this family.

In contrast to wood anatomy, the microscopic structure of bark has received little attention. Studies in wood anatomy of the Euphorbiaceae have been made by workers such as Pax (1884), Solereder (1908), Metcalfe & Chalk (1950), Mennega (1987) and others. Little is known about the bark anatomy of the Euphorbiaceae. Roth (1981) made general bark anatomical studies from samples representing 47 families, that were collected in tropical Venezuela. She included 13 genera of the Euphorbiaceae. Of these 13 genera, only four (*Croton, Drypetes, Margaritaria, Sapium*) occur in southern Africa. Although in the *Annals of Missouri Botanical Garden*, 81 (2), 1994 various characters of the Euphorbiaceae are treated on a comparative basis, information on the relevance of bark anatomical characters to the classification of this family is still lacking. The paucity of bark anatomical data can be partly ascribed to the difficulty in sectioning bark samples. Consequently, anatomical observations on the bark of the Euphorbiaceae are very scanty, and almost non-existent for most African members.

Despite all the advances in modern and orthodox medicine, traditional remedies still play a significant role in the lives of many people in Africa. Members of the Euphorbiaceae are particularly widely used for medicinal purposes in southern Africa. Watt & Breyer-Brandwijk (1962), Gelfand *et al.* (1985), Mabogo (1990) and others, cite many members of the Euphorbiaceae that are used as remedies for very many illnesses that afflict residents of southern Africa. Palmer & Pitman (1972) and Coates Palgrave (1981), quote a pertinent case of an overdue need for a bark identification service. These authors present an account published by Dr. John Maberley in the medical journal, *Lancet*, 30 September 1899. The account was about a potent medicine for curing malaria. The medicine was originally prepared from some beans and a bark, by a traditional healer. Dr. J. Maberley successfully used the medicine himself and for his patients. It was only after some 20 years that, the enthused Dr. Maberley interested Dr. I.B. Pole Evans in bark used in the medicine. Dr Pole Evans finally tracked it down to *Croton megalobotrys*.

The need for a bark identification service in South Africa has become an urgent matter. South African traditional healers are currently making concerted efforts to register with the South African Medical and Dental Council, and attempt to obtain the same privileges as conventional medical practitioners. For them to do so, it is important, *inter alia*, that the crude plant material, including bark samples, they use for their medicines should be accurately and scientifically identified. To this end, this study has initiated a long term goal of developing a computerized database system of bark characters to assist in the identification of forest trees and medicinally important bark samples. Such a system could be of service and assistance to forensic laboratories in solving court cases involving traditional medicines of dubious origins. Such a service could also help immensely in quality control of bark medicines dispensed by unscrupulous traditional healers, and by shrewd timber merchants who sell timber of low quality at exorbitant prices. The potential of bark as a source of medicines has not yet been exhausted, therefore the study of bark structure should be encouraged.

Besides being of medicinal value, bark is an important commodity in other branches of ethnobotany (Mabogo 1990). The different cultures of Africa also find their expressions in articles sculptured from wood and bark. In many African countries, the citizens still derive subsistence from the sale of articles carved from wood and bark.

In the present study the anatomy of numerous samples of mature bark representing 27 genera of southern African Euphorbiaceae were studied on a comparative basis. Features of the axial phloem parenchyma, phloem rays, sclerenchyma, dilatation tissue, calcium oxalate crystals, secretory structures, and mature periderm have been given special attention. For a real understanding of the taxonomy of this family it is necessary to draw data from all relevant botanical studies, and even from the bark anatomy of its members. This study is the first to record scientifically and in comprehensive detail, the anatomical bark structure of a large portion of taxa included in the heterogeneous, biochemically and morphologically diverse southern African woody Euphorbiaceae.

The arrangement and compilation of detailed bark descriptions was a formidable task. After lengthy discussions and research, a character list that includes a comprehensive range of bark anatomical features was compiled. The bark character list is aimed at a graphic, consistent, comprehensive and quick anatomical descriptions of all woody plants. This character list is intended for international use in the DELTA computer programme. This programme is discussed herein, under Materials and Methods (Chapter 2).

The salient aims of this study, among others, are the following:

- To develop a comprehensive character list to facilitate bark anatomical descriptions for all woody plants, using the DELTA computer programme.

- To provide detailed bark anatomical descriptions for selected woody members of southern African Euphorbiaceae.

- To explore the usefulness of bark anatomical characters for identifying unknown bark samples, e g those used in the medicinal bark trade.

- To evaluate the taxonomic significance of bark anatomical features in southern African Euphorbiaceae at all levels of the taxonomic hierarchy. It should be pointed out, however, that a comprehensive evaluation was beyond the scope of this study. The choice of the investigated species has depended on the availability of research material for providing bark anatomical descriptions using the DELTA computer programme, rather than on systematic considerations. This study should be seen as a starting point for future workers who could contribute bark anatomical data of systematic significance for the Euphorbiaceae.

In the subsequent chapters, the following will be discussed: Materials and Methods (Chapter 2); Concise Review on the Suprageneric Classification of the Euphorbiaceae (Chapter 3); Southern African Euphorbiaceae (Chapter 4); Bark Anatomical Descriptions of the Species (Chapter 5); Taxonomic Significance of Bark Anatomical Characters (Chapter 6); Discussions and Conclusions (Chapter 7). For convenience, this dissertation is presented in two parts: Part 1 comprises the text on the bark samples studied, whereas Part 2 contains all tables and figures.

CHAPTER 2

MATERIALS AND METHODS

2.1 INTRODUCTION

The bark samples were mainly collected from natural stands in southern Africa. They were processed by general botanical standard methods of fixation and preservation. The methods used were chiefly based on Van Wyk (1985).

The bark terminology used in the present study, although also drawn from elsewhere, follows mainly that of Trockenbrodt (1990).

The DELTA computer system used, was partly adopted from the IAWA wood list (Wheeler *et al.* 1989). The wood list was adapted and modified to suite bark anatomical description of all woody plants. This endeavour culminated in the compilation of a DELTA bark anatomical character list.

In this chapter the following aspects are discussed: Materials, Methods, Bark Terminology, The DELTA Computer Programme and the DELTA Bark Character List.

2.2 MATERIALS

Bark samples of 44 species representing 27 genera of the southern African woody *Euphorbiaceae* were studied. A list of these species, their voucher herbarium specimen numbers, localities, the numbers of FAA bottles containing the relevant bark samples and their *De Dalla Torre & Harms* (1958), genus numbers appears in Table 1 (see Part 2).

All voucher herbarium specimens and preserved bark samples are housed in the H.G.W.J. Schweickerdt Herbarium (PRU), Department of Botany, University of Pretoria.

2.3 METHODS

2.3.1 Collection

Bark samples measuring about 60x30 mm were collected from mature vertical boles not less that 30 mm in diameter. Incisions deep enough to reach the cambium or just extending beyond it, were made on the stems at breast-height. The incisions were made by means of a self-locking knife or a chisel and rubber hammer, depending on the hardness of the stem. The approximately 1800 mm^2 samples were then removed from the tree. If the stem diameter was about 30 mm, a hacksaw was used to cut reasonable portions of stem or branch with mature bark.

Since some of the plants studied contain latex which may be poisonous or irritating to the skin, as a precautionary measure, plastic gloves were worn when collecting samples from such trees.

The collected samples of bark were fixed and preserved in formalin-acetic acid-alcohol (FAA, Johansen 1940) contained in numbered bottles. Voucher specimens were also collected for positive identification of the plants.

2.3.2 Preparation of bark material for the light microscope

After at least 48 hours of fixation in FAA, standard procedures for wood anatomy were used to prepare bark slides for the light microscope. Transverse and radial sections, 10-20 μm thick, were cut from unembedded bark samples on a Reichert sliding microtome. These sections were supplemented by hand-cut and freeze microtome sections. At least five sections of each number were cut.

The sections were double stained in safranin O and fast-green FCF (Johansen 1940) and mounted permanently in entellan (Art. 7961, E. Merck, Darmstadt) by means of the following method, based on Van Wyk (1985):

- Place cut sections in distilled water in Petri dishes.
- Stain in safranin 0 for half an hour or overnight.
- Rinse in 50% ethyl alcohol.
- Rinse in 70% ethyl alcohol.
- Rinse twice in 96% ethyl alcohol.
- Rinse twice in 100% ethyl alcohol.
- Counterstain in fast-green for about 3 minutes.
- Wash thoroughly twice in 96% ethyl alcohol.
- Wash twice in 100% ethyl alcohol.

- Rinse in 50:50 ethyl alcohol/xylene for about 10 minutes.
- Rinse twice in xylene (xylol)
- Mount in entellan. At this stage, if necessary, slides may be turned upside down on absorbent tissue paper, gently pressed to release excess mountant and to flatten the section.
- Leave slides for about 2 days to dry at room temperature before observing them under the light microscope.

2.4 BARK TERMINOLOGY

The terminology used in bark anatomical studies is mostly borrowed from basic and generally accepted terms that are used in wood anatomy. The 'Committee of Nomenclature' of the International Association for Wood Anatomists (IAWA) has compiled and repeatedly revised an internationally applied glossary on wood anatomy, long known as the *Multilingual Glossary of terms used in wood anatomy*, (IAWA 1933, 1957, 1964; Wheeler *et al.* 1989). This glossary also includes some bark anatomy terms.

Many researchers have contributed to the pool of terms used in bark anatomy, for example Esau (1969, 1977); Schmidt (1979); Parameswaran (1980); Roth (1981); Parameswaran & Richter (1984); Baas (1985); Trockenbrodt (1989, 1990). Unless stated otherwise, the bark anatomy terminology used in this study follows Trockenbrodt (1990).

Bark is a nontechnical collective term for all the tissues outside the vascular cambium of roots and stems (Esau 1977; Cutter 1980; Roth 1981; Fahn 1982; Trockenbrodt

1990). The tissues composing the bark include secondary phloem, primary phloem, cortex, periderm and any tissue outside the last-formed periderm (rhytidome).

Bark tissues usually include sieve elements, parenchyma, sclerenchyma, dilatation tissue, secretory structures and calcium oxalate crystals. In this study the following bark structures were given special attention: axial phloem parenchyma, phloem rays, sclerenchyma, dilatation tissue, calcium oxalate crystals, secretory structures, periderm and cortex. The distribution of the main bark tissues is diagrammatically shown in Figure 1 (see Part 2). Rhytidome constitutes the so-called outer bark and is composed of the dead portion of the bark comprising layers of periderms and layers of dead secondary phloem (Esau 1977). In this study rhytidome is not considered, because it is brittle and usually disintegrates during sectioning.

2.4.1 Sieve elements

Analogous with the classification of tracheary elements into vessels members, the conducting elements of angiosperm phloem, called collectively sieve tubes, may be segregated into sieve elements and companion cells (Esau 1965). Trockenbrodt (1990) supports this classification.

The characteristics of the wall structures — pits and perforation plates in tracheary elements are respectively analogous to sieve areas and sieve plates in sieve elements (Esau 1965). Sieve areas are present on lateral walls of sieve elements as well as on end walls, which may be transverse or oblique. Walls which show one or more sieve areas are generally called sieve plates (Zahur 1959; Esau 1969, 1977; Fahn 1974).

If a sieve plate consists of only one sieve area it is called simple. If one sieve plate is formed of several sieve areas it is compound (Trockenbrodt 1990). Depending on the arrangement of sieve areas, sieve plates can be described as scalariform or reticulate (Esau 1969).

The cell walls of sieve elements are commonly described as primary (Parameswaran & Liese 1970). Nevertheless, an additional layer may be visible. This layer is referred to as the nacreous wall (Esau 1977).

Sieve elements commonly contain variable amounts of a relatively viscous substance known as slime. This slime consists mainly of proteins (P-proteins) (Esau 1965; Fahn 1982). Junction complexes are relatively large, complex and unusual structures (Tippet & Hill 1984). In transverse section they appear as a lattice between two sieve tubes, whereas in longitudinal sections they resemble a series of folds. According to Tippet & Hill (1984), so far junction complexes have only been found in species with relatively thick conducting phloem.

Sieve elements and companion cells develop from the same cambial initial. Such a meristematic cell divides longitudinally once or several times and one of the resulting cells forms the sieve tube member and the others develop into companion cells (Fahn 1982).

Sieve elements, however, were not considered in the present study for a number of reasons. *Inter alia*, difficulties are experienced in identifying sieve elements with certainty with the light microscope (Cutter 1979). Sometimes the nacreous layer is detectable only with the aid of electron microscopy (Esau 1969; Cronshaw 1975). Because of the peculiar nature of sieve elements, they are technically difficult to study (Cutter 1979). The methods required to study sieve elements are expensive, cumbersome, involved and time-consuming. Sieve elements collapse easily when being processed for microscope slides.

2.4.2 Axial phloem parenchyma

These are parenchyma cells in the axial, longitudinal or vertical system of secondary phloem as contrasted with the horizontal phloem ray parenchyma cells (Esau 1977). They are oriented with their longest diameter parallel with the main axis of the stem. The axial phloem parenchyma is derived from the fusiform cambial initials.

2.4.3 Phloem rays

A phloem ray is a panel of parenchyma tissue which is variable in height and width (Esau 1977). The phloem ray is radially oriented in secondary phloem and is derived from cambial ray initials. Phloem rays are continuous with the xylem rays.

2.4.4 Sclerenchyma

This tissue is composed of cells that are variable in shape and size, and have more or less lignified secondary walls. It is a supporting or a mechanical tissue. The cells composing this tissue may or may not be devoid of protoplast at maturity. Sclerenchyma includes fibres, fibre-sclereids and sclereids. This classification is, however, controversial, because of the considerable variation in shape shown by these tissues (Rao & Bhupal 1973; Parameswaran 1980; Trockenbrodt 1990).

Fibres are long slender cells which are developed directly from fusiform cambial initials, and have thickened secondary walls, as well as apical growth.

Sclereids, on the other hand, are cells of variable form and size which develop from living parenchyma cells of the axial and radial systems. They are characterized by lignified polylamellate secondary walls with ramified pitting. Sclereids are shorter than fibres and typically lack apical growth. The typology of sclereids used in this study is according to Rao and Bhupal (1973).

A fibre-sclereid is a sclerenchyma cell with characteristics intermediate between those of a fibre and a sclereid (Esau 1977). Fibre-sclereids possess a polylamellate wall structure, just like sclereids, but they are elongated through apical growth (Parameswaran 1975).

Trockenbrodt (1990) contends that Holheide (1951), Esau (1977), Parameswaran & Liese (1970), Fahn (1974), Parameswaran (1975, 1980) and Roth (1981) give contradictory definitions of fibre-sclereids in general and sclerenchymatous cells in particular. He holds that clarifying the terminology of sclerenchyma requires extensive ontogenetical investigations at the ultrastructural level, and that such a type of classification based on developmental investigations is not absolutely necessary for comparative anatomical studies.

2.4.5 Dilatation tissue

The tangential strain in bark tissues caused by secondary growth or development is compensated for additional growth, called dilatation or expansion growth. Dilatation growth occurs through cell divisions in axial phloem parenchyma and/or phloem ray parenchyma, and results in the increase in circumference of the bark. The cortex and even the epidermis may show dilatation growth as well (Reinders & Reinders-Gouwentak 1961; Esau 1969).

The so-called dilatation meristems develop in some barks and divide radially (Reinders & Reinders-Gouwentak 1961; Esau 1969; Roth 1981). Whitmore (1962) introduced the term pseudocortex which applies to the cortex-like tissue zone beneath the periderm in some trees. Van Wyk (1985) refers to expansion tissue as a synonym for dilatation tissue. He also uses the term pseudocortex but considers it to consist of both primary tissue (cortex remnants) and dilatation tissue, unlike Whitmore (1962) who considers pseudocortex to be developed by dilatation growth of the secondary phloem.

2.4.6 Calcium oxalate crystals

Calcium oxalate crystals occur in bark tissues in different forms. These include prisms, druses, styloids, acicular crystals, raphides and crystal sand.

Prisms are rectangular or pyramidal crystals; druses are spheroidal aggregates of prismatic crystals; styloids are long prismatic crystals tappered off at both ends into a blade; acicular crystals are thin, sharp-pointed and needle-shaped; raphides are aggregated bundles of thin elongated crystals with tapering off points and are enclosed in raphide sacs, and crystal sand are very small prisms usually occurring in masses (Fahn 1982). The appearance, location and type of crystal is often used in taxonomy (Fahn 1982).

2.4.7 Secretory structures

Authors are at variance with regard to the precise definitions of secretory structures and their secretions. Roth (1981) divides the secretory systems into four categories, namely secretory idioblasts, secretory cavities, laticifers and secretory canals. Even the IAWA glossary (1964) is devoid of clear-cut definitions of the secretory system. This has led to a multitude of terms referring to the secretory system (Trockenbrodt 1990).

Trockenbrodt (1990) recognizes two categories of secretory structures, namely secretory cells and intercellular spaces. The category of secretory cells includes not only oil cells, mucilage or slime cells, tanniniferous cells, but also articulated laticifers (composed of several secretory cells) and non-articulated laticifers. He describes the secretory intercellular spaces according to their shape and contents. The terms canals or ducts he reserves for extremely long, slender intercellular spaces that are filled with secretions.

2.4.8 Periderm

Periderm consists of the phellem (cork), phellogen (cork cambium) and phelloderm. Phellogen is a meristematic layer that divides outwards tangentially to form layers of phellem cells, and inwards to develop the phelloderm tissue. This definition of periderm and its constituent parts is generally accepted (Trockenbrodt 1990).

The periderm which replaces the epidermis when secondary growth starts is called the first-formed periderm (Borger & Kozlowski 1972; Mullick & Jensen 1973; Fahn 1974; Esau 1977; Liphshitz & Waisel 1980). Periderms that are formed after the first-formed periderm are (sub)sequent periderms (Fahn 1974; Roth 1981; Van Wyk 1985; Trockenbrodt 1990). In this study the latter periderms are referred to as mature periderm. The tissue on the outside of the last-formed periderm (cortex, primary phloem, older periderms) is called rhytidome (Esau 1969, 1977, 1979; Parameswaran & Liese 1970; Fahn 1974; Roth 1981). These cells are often less strongly suberized.

Phelloderm is generally parenchymatous. It may or may not be lignified or stratified. Where cortex occurs the phelloderm cells may be distinguished by their radial orientation.

Lenticels are more or less clearly determined regions of the periderm which can be distinguished from normal periderm by an increased activity of the phellogen and which guarantee a better gas exchange due to numerous intercellular spaces (Wutz 1955). This loose tissue with intercellular spaces that is derived from the phellogen in lenticels is called filling tissue (Esau 1977; Roth 1981).

2.4.9 Cortex

Cortex is primary ground tissue occupying the region between the vascular system and the epidermis in stems and roots (Esau 1977). It belongs neither to the epidermis, the periderm nor the phloem (Trockenbrodt 1990). Where and when the cortex persists in mature woody stems, it forms part of the bark, because it is outside the vascular cambium and even outside the vascular system.

2.5 THE DELTA COMPUTER PROGRAMME

The DELTA system (DEscription Language for TAxonomy) is a standardized format for coding taxonomic descriptions (Patridge *et al.* 1988). It is a generalized system for handling all the different kinds of descriptive data used by taxonomists, without information loss, in an easy-to-use format designed to minimize encoding errors (Watson & Milne 1972, Dallwitz 1980, Dallwitz & Paine 1986). DELTA was adopted as the standard format for taxonomic descriptions at the 1988 meeting of the Taxonomic Databases Working Group for Plant Sciences.

2.5.1 Programme

Compilation of a character list is the fist step for the use of the DELTA computer programme. The character list of anatomical bark features used in this study, was compiled during the present study and is listed under 2.6.

The character list was converted to a format suitable for the DELTA programme. It was entered into a personal computer and saved as the file, CHARS. CHARS is a character file which lists the characters and an accompanying list of possible character states. The SPECS — the specifications file which contains information about data in CHARS, could then be written.

A convenient version of the character list was compiled to enable easy coding (see 2.6.10). This takes the form of two blocks before each character state; one for recording presence, and the other for recording abundance according to Schmid (1982). The features of each bark character are filled in on the list and then entered as the ITEMS file on the computer in the form of numeric codes.

CONFOR is a format-conversion programme. Three such programmes were used, namely CONFOR-TONAT to convert the ITEMS codes into a natural-language description, CONFOR-CHECK to check for possible errors in encoding and CONFOR-TIDY to edit the description produced by CONFOR-TONAT programme.

The operating instructions for the DELTA package are given in Dallwitz & Paine (1986) and Patridge *et al.* (1988). A brief review of basic concepts and procedures can be found in De Pernia & Miller (1991).

2.6 DELTA BARK CHARACTER LIST

The DELTA bark character list was compiled after numerous observations had been carried out and lengthy discussions held. Mainly anatomical characters were used. A few morphological characters such as lentical characteristics were included for completeness of description.

A brief overview of the character in the list follows (the '#' sign refers to the numbers of particular characters in the list):

2.6.1 **Sieve elements** (#1—10)

Characters and possible character states were extracted from Zahur (1959), Esau (1979), Van Wyk (1985) and Tippet & Hill (1984). Zahur (1959) is followed closely, although his terminology has been updated according to Trockenbrodt (1990).

Sieve tube junction complexes (#5) have been found to be taxonomically significant at the generic level of Myrtaceae (Tippet & Hill 1984). Esau (1979) distinguishes between simple and compound sieve plates, whereas the IAWA wood list (Wheeler *et al.* 1986) divides vessel perforation plates into simple, scalariform or reticulate and/or other types (#8). The number of sieve areas per plate (#9) was found by Van Wyk (1985) to be useful, although somewhat difficult to observe. Similarly, companion cells (#10) are not always distinguishable.

2.6.2 **Axial phloem parenchyma** (#11—15)

The distribution of axial phloem parenchyma (#11) and cell shapes (#12) have been found to be almost species specific in some cases. Tannin is strongly stained in most bark sections (#13).

Roth (1981) found that tanniniferous cells were so frequent that they could be omitted from detailed descriptions! Van Wyk (1985) found the tannin content of axial phloem parenchyma to be species specific in some cases. Because tannin content varies from tissue to tissue this character is included under each tissue type, for description purposes. Similarly, presence/absence and abundance of calcium oxalate crystals (#14) are recorded for each tissue type. The distribution pattern of these crystals (#15), which is often characteristic, is recorded by means of a text character.

2.6.3 **Phloem rays** (#16—28)

According to Trockenbrodt (1990), the phloem rays can either be homocellular or heterocellular (#16). The categories of ray width, height and number (#17, 18 and 19) follow Wheeler *et al.* (1989). The pattern produced by the course of the rays (#20) was found to be species specific by Roth (1981), who also observed that rays traversing sclerenchymatous tissue may become lignified or remain parenchymatous (#21). Characters for aggregate rays and tile cells (#22 and 25) were included, because they are often diagnostic at the species level owing to their scarcity.

2.6.4 **Sclerenchyma** (#29—40)

Sclerenchyma is not always present in secondary phloem, so the first character (#29) of this category establishes its presence or absence. Character #30 encompasses all traditional states between fibres and sclereids. Roth (1981) places great emphasis on the taxonomic importance of sclerenchyma distribution (#31). Outlines of plates and aggregates of sclerenchyma (#32) in transverse section are fairly constant for a given taxon (Roth 1981). Characters #30—40 elaborate on the type of sclerenchyma.

Rao & Bhupal (1973) provide a good classification system of sclereids, but their recommendations are too detailed to include in their entirety. Examples for their classification are given in the character list as a point of departure.

2.6.5 **Dilatation tissue** (#41—52)

Roth (1981) found dilatation tissue to be species-specific which makes it useful in identification. The first character (#41) determines the extent of development of dilatation tissue. The derivation and types of dilatation tissue (#42 and 43), were found to be diagnostic at generic level (Roth 1981). Five characters (#45—49) are provided for the recording of sclerenchyma in the dilatation tissue. The presence and the degree of development of a sclerenchyma ring (#48) is easily observable and provides a good diagnostic character (Richter 1981). Characters #50—52 deal with three easily recognized features that characterize the dilatation tissue.

2.6.6 **Calcium oxalate crystals** (#53—69)

This category provides for information given about the occurrence of each crystal type in the different tissue types. Crystals are classified by Roth (1981) into solitary rhomboids (prisms) (#55), druses (#56), styloids (#57), raphides (#59), crystal sand (#60) and other form, for instance, acicular crystals (#58). The location and association of crystals with sclerenchyma is considered to be taxonomically very important (Roth 1981).

Axial chambered crystalliferous strands presence or absence (#67), distribution (#68) and the distinction between their cell walls remaining parenchymatous or becoming lignified (#69) are considered to have taxonomic value.

2.6.7 **Secretory structures** (#70—74)

Metcalfe & Chalk (1950) describe secretory structures as being 'of diagnostic value ... because of their restricted occurrence and the ease with which they may be seen'. The first character of this section (#70) distinguishes between the presence of secretory structures, their absence (except for not notably enlarged tanniniferous cells) and their complete absence. Character #71 provides means of recording the type of secretory structures. Distribution and other attributes of secretory structures (#72) are recorded by means of a text character.

2.6.8 **Periderm** (#75—111)

- First-formed periderm (#75—76)

The pattern of periderm initiation is known to determine to a large extent the structure of the rhytidome and eventually the bark surface pattern (Van Wyk 1985). Ontogenetic studies on young shoots are usually required to establish the tissue of origin, but once determined the character is of high diagnostic value.

- Mature periderm (#77—111)

Roth (1981) found the distinction between ring bark and scale bark (#77) to be of little use for identification, because most barks are scale barks. However, this makes the character useful taxonomically. The thickness of the periderm (#78), is an indication to the thickness of the suberized layer and shows good structure-function correlation. The presence of cells with lignified walls (phelloids) in the phellem (#85) is diagnostic for many species. Observation of cell shape can be fairly subjective (#91). An approach which compares the radial and tangential diameters gives an approximation of tangentially elongated, radially elongated and square shapes. The phellem may be rich in idioblasts (#95) and they are valuable taxonomic characters in some taxa.

Roth (1981) notes that a well developed and differentiated phelloderm (#99) may help in identification. Stratification (#100) is an important character, and its presence in phelloderm is often accompanied by sclerification and/or stratified secondary phloem (Roth 1981). The secondary phloem parenchyma, in some cases (even if covered by rhytidome), appears to have a photosynthetic function in which case the presence of chloroplasts (#109) in the phelloderm is a common phenomenon (Roth 1981).

2.6.9 **Cortex** (#112 & 113)

Cortex is always present in young stems. If it occurs in the bark it has persisted from the young stem. Character #112 establishes presence/absence of the cortex. The cortex may contain sclereids, secretory cells and laticifers (Fahn 1982). This last characcter #113 is recorded by means of a text character.

2.6.10 The Character List

In compiling the character list in the present study, the approach of the IAWA wood list (Wheeler *et al.* 1989) was used as basis and numeric characters were converted into ordered multistate characters wherever it was feasible. Numerous text characters have been included to allow for elaboration on certain features that may be peculiar to a taxon.

The hash (#) before a number (e.g. #6) denotes the character number six. The phrase or term between the angle brackets (< ... >) stresses the aspect of the character that should be selected from the character states numbered 1, 2, 3 etc. This phrase or term is not coded and is therefore not entered into the ITEMS file. There are two blocks (□□) before each character state. One block is for recording presence, by a tick (✓) or a cross (X). The second block is for recording abundance by inserting an alphabetic characters (A—J) according to the descriptors used to indicate abundance and frequency by Schmid (1982). Text characters that do not have character states (e.g. #9 sieve areas < number: recorded range >/), and are recorded by means of a text phrase.

The printed character list used for the coding of the bark sample follows. Note that to make it more user-friendly (e.g. the addition of blocks and guiding arrows), it differs slightly from the version entered as the CHARS file in DELTA. The same form was used to code all samples for a particular taxon — thus indication of abundance or frequency usually reflects infraspecific variation.

Family: ....

Genus: . . . .

Species: . . . .

Slide no.: . . . .

A = absent (0%); B = very rarely (<2%); C = rarely (2—4%); D = very occasionally (5—10%); E = occasionally (11—30%); F = often (31—54%); G = very often (55—64%); H = usually (65—94%); I = nearly always (95—99%); J = always (100%)

Sieve elements

#1. sieve elements <arrangement in the phloem parenchyma>/

☐ ☐ 1. scattered singly/

☐ ☐ 2. in groups ('pore multiples')/

☐ ☐ 3. forming interrupted tangential bands <especially noticeable in the collapsed zone of the secondary phloem>/

#2. sieve element type/

☐ ☐ 1. essentially long, usually with oblique sieve plates with 10 or more sieve areas (type I)/

☐ ☐ 2. intermediate in length, usually sieve plates with under 10 sieve areas (type II)/

☐ ☐ 3. usually short with slightly oblique to transverse, simple sieve plates (type III)/

#3. sieve elements <width>/

☐ ☐ 1. wider than surrounding parenchyma cells/

☐ ☐ 2. narrower than surrounding parenchyma cells/

☐ ☐ 3. of similar width to parenchyma cells/

#4. <sieve element> slime/

- ☐ ☐ 1. copious and persistent, occurs as a spindle-shaped body with a definite outline/
- ☐ ☐ 2. copious and dispersed/
- ☐ ☐ 3. scanty/
- ☐ ☐ 4. not observed/

#5. <sieve tube> junction complexes between elements/

- ☐ ☐ 1. abundant/
- ☐ ☐ 2. sparse
- ☐ ☐ 3. not observed/

#6. <sieve element> walls <of certain sieve elements> with nacreous layer/

- ☐ ☐ 1. present, well defined/
- ☐ ☐ 2. present, poorly defined/
- ☐ ☐ 3. absent/

#7. sieve plates <orientation>/

- ☐ ☐ 1. oblique/
- ☐ ☐ 2. transverse/

#8. sieve plates/

- ☐ ☐ 1. simple <bearing only one sieve area>/
- ☐ ☐ 2. scalariform (compound) <sieve areas arranged in one row>/
- ☐ ☐ 3. reticulate (compound) <sieve areas arranged in a net-like pattern>/
- ☐ ☐ 4. compound (reticulate or scalariform)/

#9. sieve areas <number: record range>/

....per plate

#10. <companion cells, e.g. abundance, shape>/

companion cells ....

Axial phloem parenchyma

#11. axial phloem parenchyma <arrangement, as seen in T.S.>/

☐ ☐ 1. diffuse between sieve tube elements/

☐ ☐ 2. in weak tangential lines/

☐ ☐ 3. in conspicuous tangential bands/

#12. <axial phloem parenchyma cell shape, to be established in L.S. in secondary phloem not affected by dilatation growth, preferably in the non-collapse zone> cells/

☐ ☐ 1. axially elongated/

☐ ☐ 2. more-or-less isodiametric/

#13. <axial phloem parenchyma> tanniniferous cells (not notably enlarged)/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#14. <axial phloem parenchyma> calcium oxalate crystals/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/ → #16

#15. <distribution of calcium oxalate crystals, e.g. randomly dispersed; in short tangential rows of crystal cells alternating with rows of phloem parenchyma>/

....

....

Phloem rays

#16. phloem rays <homocellular vs heterocellular>/

☐ ☐ 1. homocellular, typical procumbent/

☐ ☐ 2. homocellular, typically square and/or upright cells/

☐ ☐ 3. homocellular, typically hexagonal/isodiametric/

☐ ☐ 4. heterocellular, one row of upright and/or square cells/

☐ ☐ 5. heterocellular, 2—4 rows of upright and/or square cells/

☐ ☐ 6. heterocellular, more than 4 rows of upright and/or square cells/

☐ ☐ 7. heterocellular, multiseriate portion(s) as wide as uniseriate portions/

☐ ☐ 8. heterocellular, with procumbent, square and upright cells mixed/

☐ ☐ 9. not present <rayless>/ → #29

#17. rays <width categories>/

☐ ☐ 1. exclusively uniseriate/

☐ ☐ 2. 1—3 seriate/

☐ ☐ 3. larger rays commonly 4—10 seriate/

☐ ☐ 4. larger rays commonly wider than 10 seriate/

#18. number of rays <per linear millimeter>/

☐ ☐ 1. less than 4 per mm/

☐ ☐ 2. 4—12 per mm/

☐ ☐ 3. 12 or more per mm/

#19. ray height <the large rays commonly exceeding 1 mm or not, as seen in L.S.>/

☐ ☐ 1. less than 1 mm/

☐ ☐ 2. more than 1 mm/

#20. course <of phloem rays>/

☐ ☐ 1. more-or-less straight/

☐ ☐ 2. irregular/

☐ ☐ 3. undulated/

☐ ☐ 4. anastomosing <rare>/

#21. portion of rays traversing or adjacent to sclerenchyma/

☐ ☐ 1. lignified/

☐ ☐ 2. remaining parenchymatous/

☐ ☐ 3. not observed/

#22. aggregate rays <record degree of fusion of neighbouring cells in ITEMS file>/

☐ ☐ 1. present/

☐ ☐ 2. absent/

#23. <phloem rays> storied structure <as seen in tangential L.S. in secondary phloem not affected by dilatation growth, preferably near the vascular cambium>/

☐ ☐ 1. present <rare>/

☐ ☐ 2. absent/

#24. <ray cell features e.g. thin walled, abundantly pitted>/

ray cells ....

....

#25. tile cells <apparently empty upright ray cells occurring the intemediate horizontal series usually interspersed among the procumbent cells; rare, not yet recorded in uniseriate rays>/

☐ ☐ 1. present/

☐ ☐ 2. absent/

#26. <phloem rays> tanniniferous cells (not notably enlarged)/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#27. <phloem rays> calcium oxalate crystals/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#28. <calcium oxalate crystals e.g. type, variability, distribution patterns>/

....

....

Sclerenchyma

#29. sclerenchyma (in secondary phloem not affected by dilatation growth), <preferably established in the non-collapsed zone; note that walls of elements may remain unlignified, e.g. gelatinous or cellulosic; the latter state easily overlooked and best detected under polarized optics; lignified chambered crystalliferous strands considered under #67, #68 & #69>/

☐ ☐ 1. present/

☐ ☐ 2. absent/ → #41

#30. <sclerenchyma type> comprising/

☐ ☐ 1. lignified fibres/ → #31, [#32], #33, #40

☐ ☐ 2. lignified fibre-sclereids <all transitional states between fibres and sclereids>/ → #31, [#32], #37, #39—40

☐ ☐ 3. lignified sclereids/ → #31, [#32], #38, #39—40

☐ ☐ 4. gelatinous fibres/ → #31, [#32], #38, #39—40

☐ ☐ 5. cellulosic fibres/ → #31, [#32], #33—35, #40

☐ ☐ 6. cellulosic sclereids/ → #31, [#32], #38, #39—40

#31. sclerenchyma distribution/

☐ ☐ 1. scattered with solitary elements/

☐ ☐ 2. forming scattered aggregates of loosely arranged elements/ → #32

☐ ☐ 3. forming loose tangential groups/ → #32

☐ ☐ 4. forming regular compact groups/ → #32

☐ ☐ 5. forming irregular compact groups/ → #32

☐ ☐ 6. forming compact staggered plates/ → #32

☐ ☐ 7. forming compact storied plates <superposed>/ → #32

☐ ☐ 8. arranged in discontinuous tangential bands/

☐ ☐ 9. forming discontinuous concentric rings <rare>/

☐ ☐ 10. forming continuous concentric rings <rare>/

☐ ☐ 11. forming <short, long or undulating> radial rows <rare>/

#32. <outline of plates and aggregates in transverse section, e.g. circular, tangential, elliptic, ovate, obovate, lenticular and irregular>/

....

....in outline

#33. fibres <radial diameter best established in T.S.>/

....μm in radial diameter/

#34. fibres <type>/

☐ ☐ 1. septate/

☐ ☐ 2. non-septate/

#35. <fibre> walls/

☐ ☐ 1. very thin/

☐ ☐ 2. thin to thick/

☐ ☐ 3. very thick/

#37. gelatinous fibres <wall staining characters> with S_1 layer/

☐ ☐ 1. distinctly lignified/

☐ ☐ 2. weakly lignified/

☐ ☐ 3. non lignified/

#37. <fibre-sclereid type, e.g. radially elongated>/

fibres-sclereids...

....

#38. <sclereid shape, e.g. spheroidal, vesiculose, vermiform, fusiform, filiform, polymorphic (for a sub-division of this category see Rao & Bhupal 1973); size of lumen>/

sclereid shape ....
....

#39. <sclereid> walls <course>/

☐ ☐ 1. more-or-less even/
☐ ☐ 2. slightly uneven/
☐ ☐ 3. undulating/

#40. <lumen characteristics e.g. dimensions, shape (irregular, round, square, hexagonal, with prisms of calcium oxalate, etc.)>/

lumen ....
....

Dilatation tissue

#41. dilatation tissue/

☐ ☐ 1. well developed/
☐ ☐ 2. poorly developed or absent/ → #53

#42. <dilatation tissue> derived from/

☐ ☐ 1. phloem parenchyma only/
☐ ☐ 2. rays only/
☐ ☐ 3. phloem parenchyma and rays/

#43. <type of dilatation tissue>/

☐ ☐ 1. irregular ('diffuse' type)/
☐ ☐ 2. continuous, forming a broad zone ('pseudocortex')/
☐ ☐ 3. continuous, interdigitizing with the secondary phloem/
☐ ☐ 4. rays dilated, but not regularly wedge-shaped/
☐ ☐ 5. rays regularly dilated, wedge-shaped/
☐ ☐ 6. phloem parenchyma regularly dilated, wedge-shaped/

#44. well-defined dilatation meristem(s)/

☐ ☐ 1. present/

☐ ☐ 2. absent/

#45. sclerenchyma <in dilatation zone; only secondary formed sclereids (excluding primary phloem fibres), best established in old dilatation tissue>/

☐ ☐ 1. present/

☐ ☐ 2. absent/ → #50

#46. <type of secondarily derived sclereids e.g. spheroidal, vesiculose, vermiform, fusiform, filiform, polymorphic (for a sub-division of this category see Rao & Bhupal 1973), fibres, fibre-sclereids>/

sclereids ....

....

#47. <distribution of secondarily-formed sclerenchyma in dilatation tissue>/

☐ ☐ 1. irregularly scattered as idioblasts/

☐ ☐ 2. irregularly dispersed as clusters/

☐ ☐ 3. mainly associated with aggregates of primary sclerenchyma/

#48. sclerenchyma ring (persistent primary phloem caps or fibres)/

☐ ☐ 1. present, well developed/

☐ ☐ 2. present, poorly developed/

☐ ☐ 3. present, very poorly developed, only caps/

☐ ☐ 4. absent/

#49. primary phloem fibres <sclerenchyma attributes; wall characters, e.g. cellulosic, lignified, polylamellate>/

....

....

#50. <dilatation tissue> tanniniferous cells (not notably enlarged)/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#51. calcium oxalate crystals <in dilatation tissue>/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/ → #53

#52. <calcium oxalate crystals e.g. type, variability, distribution patterns>/

....

....

Calcium oxalate crystals

#53. calcium oxalate crystals/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/ → #70

#54. <crystal type>

☐ ☐ 1. prisms/ → #55, #61

☐ ☐ 2. druses/ → #56, #62

☐ ☐ 3. styloids/ → #57, #63

☐ ☐ 4. acicular/ → #58, #65

☐ ☐ 5. raphides/ → #59, #65

☐ ☐ 6. crystal sand/ → #60, #66

#55. <prisms, as seen in T.S.> located mainly in/

☐ ☐ 1. axial phloem parenchyma/

☐ ☐ 2. ray cells/

☐ ☐ 3. sclerenchyma/
☐ ☐ 4. crystalliferous cells, wreathing the sclerenchyma/
☐ ☐ 5. crystalliferous cells, associated with fibres/
☐ ☐ 6. dilatation tissue/
☐ ☐ 7. phellem/
☐ ☐ 8. phelloderm/
☐ ☐ 9. cortex/

#56. <druses, as seen in T.S.> located mainly in/
☐ ☐ 1. axial phloem parenchyma/
☐ ☐ 2. ray cells/
☐ ☐ 3. sclerenchyma/
☐ ☐ 4. crystalliferous cells, wreathing the sclerenchyma/
☐ ☐ 5. crystalliferous cells, associated with fibres/
☐ ☐ 6. dilatation tissue/
☐ ☐ 7. phellem/
☐ ☐ 8. phelloderm/
☐ ☐ 9. cortex/

#57. <styloids, as seen in T.S.> located mainly in/
☐ ☐ 1. axial phloem parenchyma/
☐ ☐ 2. ray cells/
☐ ☐ 3. sclerenchyma/
☐ ☐ 4. crystalliferous cells, wreathing the sclerenchyma/
☐ ☐ 5. crystalliferous cells, associated with fibres/
☐ ☐ 6. dilatation tissue/
☐ ☐ 7. phellem/
☐ ☐ 8. phelloderm/
☐ ☐ 9. cortex/

#58. <acicular crystals, as seen in T.S.> located mainly in/
☐ ☐ 1. axial phloem parenchyma/
☐ ☐ 2. ray cells/

☐ ☐ 3. sclerenchyma/

☐ ☐ 4. crystalliferous cells, wreathing the sclerenchyma/

☐ ☐ 5. crystalliferous cells, associated with fibres/

☐ ☐ 6. dilatation tissue/

☐ ☐ 7. phellem/

☐ ☐ 8. phelloderm/

☐ ☐ 9. cortex/

#59. <raphides, as seen in T.S.> located mainly in/

☐ ☐ 1. axial phloem parenchyma/

☐ ☐ 2. ray cells/

☐ ☐ 3. sclerenchyma/

☐ ☐ 4. crystalliferous cells, wreathing the sclerenchyma/

☐ ☐ 5. crystalliferous cells, associated with fibres/

☐ ☐ 6. dilatation tissue/

☐ ☐ 7. phellem/

☐ ☐ 8. phelloderm/

☐ ☐ 9. cortex/

#60. <crystal sand, as seen in T.S.> located mainly in/

☐ ☐ 1. axial phloem parenchyma/

☐ ☐ 2. ray cells/

☐ ☐ 3. sclerenchyma/

☐ ☐ 4. crystalliferous cells, wreathing the sclerenchyma/

☐ ☐ 5. crystalliferous cells, associated with fibres/

☐ ☐ 6. dilatation tissue/

☐ ☐ 7. phellem/

☐ ☐ 8. phelloderm/

☐ ☐ 9. cortex/

#61. prisms, if associated with sclerenchyma/

☐ ☐ 1. not encased in scleretic elements/

☐ ☐ 2. encased within sclereids/

☐ ☐ 3. encased within fibre-sclereids/
☐ ☐ 4. encased within fibres/
☐ ☐ 5. encased within chambered axial strands associated with fibres only/
☐ ☐ 6. encased within chambered axial strands/
☐ ☐ 7. encased within secondarily formed sclereids in the dilatation zone/

#62. druses, if associated with sclerenchyma/
☐ ☐ 1. not encased in scleretic elements/
☐ ☐ 2. encased within sclereids/
☐ ☐ 3. encased within fibre-sclereids/
☐ ☐ 4. encased within fibres/
☐ ☐ 5. encased within chambered axial strands associated with fibres only/
☐ ☐ 6. encased within chambered axial strands/
☐ ☐ 7. encased within secondarily formed sclereids in the dilatation zone/

#63. styloids, if associated with sclerenchyma/
☐ ☐ 1. not encased in scleretic elements/
☐ ☐ 2. encased within sclereids/
☐ ☐ 3. encased within fibre-sclereids/
☐ ☐ 4. encased within fibres/
☐ ☐ 5. encased within chambered axial strands associated with fibres only/
☐ ☐ 6. encased within chambered axial strands/
☐ ☐ 7. encased within secondarily formed sclereids in the dilatation zone/

#64. acicular crystals, if associated with sclerenchyma/
☐ ☐ 1. not encased in scleretic elements/
☐ ☐ 2. encased within sclereids/
☐ ☐ 3. encased within fibre-sclereids/
☐ ☐ 4. encased within fibres/
☐ ☐ 5. encased within chambered axial strands associated with fibres only/
☐ ☐ 6. encased within chambered axial strands/
☐ ☐ 7. encased within secondarily formed sclereids in the dilatation zone/

#65. raphides, if associated with sclerenchyma/

☐ ☐ 1. not encased in scleretic elements/

☐ ☐ 2. encased within sclereids/

☐ ☐ 3. encased within fibre-sclereids/

☐ ☐ 4. encased within fibres/

☐ ☐ 5. encased within chambered axial strands associated with fibres only/

☐ ☐ 6. encased within chambered axial strands/

☐ ☐ 7. encased within secondarily formed sclereids in the dilatation zone/

#66. crystal sand, if associated with sclerenchyma/

☐ ☐ 1. not encased in scleretic elements/

☐ ☐ 2. encased within sclereids/

☐ ☐ 3. encased within fibre-sclereids/

☐ ☐ 4. encased within fibres/

☐ ☐ 5. encased within chambered axial strands associated with fibres only/

☐ ☐ 6. encased within chambered axial strands/

☐ ☐ 7. encased within secondarily formed sclereids in the dilatation zone/

#67. axially arranged chambered crystalliferous strands (not associated with sclerenchyma) <to be established in L.S. in that secondary phloem not affected by dilatation growth, preferably in the non-collapsed zone>/

☐ ☐ 1. present/

☐ ☐ 2. absent/ → #70

#68. <distribution of axial chambered crystalliferous strands in secondary phloem; to be established in T.S.>

☐ ☐ 1. randomly dispersed throughout secondary phloem/

☐ ☐ 2. arranged in short tangential lines/

☐ ☐ 3. mainly associated with sclerenchyma/

#69. <axial chambered crystalliferous strands; lignification of> cell walls/

☐ ☐ 1. sclerified/

☐ ☐ 2. remaining parenchymatous/

Secretory structures

#70. secretory structures/

☐ ☐ 1. present/

☐ ☐ 2. absent (except for not notably enlarged tanniniferous cells)/ → #73

☐ ☐ 3. absent/ → #75

#71. <secretory structures> composed of/

☐ ☐ 1. oil cells/

☐ ☐ 2. mucilaginous <slime> cells/

☐ ☐ 3. enlarged tanniniferous cells <c.f. #70.2>/

☐ ☐ 4. <secretory> ducts <canals>/

☐ ☐ 5. articulated laticifers/

☐ ☐ 6. non-articulated laticifers/

☐ ☐ 7. regular <secretory> cavities <more-or-less spherical>/

☐ ☐ 8. an irregular system of cavities/

#72. <distribution and other attributes of secretory structures, e.g. branching. Where duct sheath is present record whether aliform, aliform-confluent, in tangential bands or in concentric rings>/

....

....

#73. <secretory structures> tanniniferous cells (not notably enlarged)/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

#74. <distribution and other attributes of tanniniferous cells (c.f. #70), e.g. mainly in rays, mainly in phloem parenchyma, mainly in phelloderm, mainly in dilatation tissue; differential staining of different types of cells apparent>/

....

....

Periderm

First-formed periderm

#75. first-formed periderm originating <only possible to establish in young twigs>/

- ☐ ☐ 1. epidermally/
- ☐ ☐ 2. subdermally/
- ☐ ☐ 3. in cortex/
- ☐ ☐ 4. in primary phloem/
- ☐ ☐ 5. in secondary phloem <rare>/

#76. first-formed periderm <course>/

- ☐ ☐ 1. as a continuous cylinder around the stem circumference/
- ☐ ☐ 2. discontinuous, initiated locally in certain areas from where it spreads, eventually becoming continuous/

Mature periderm

#77. mature periderm <type; best established macroscopically>/

- ☐ ☐ 1. consisting of interconnected scallop-shaped segments (scale bark)/
- ☐ ☐ 2. forming a continuous ring around the whole circumference of the stem; different periderms not anastomosing (ring bark) <rare>/

#78. periderm <thickness>/

....mm thick/

#79. <number of> periderms <best established on the transverse plane of dried unsectioned material>/

- ☐ ☐ 1. one in number/
- ☐ ☐ 2. two to three in number/
- ☐ ☐ 3. four or more in number/

#80. <periderm arrangement as seen in T.S.>/

☐ ☐ 1. ramified (net-like)/

☐ ☐ 2. superposed in stories <chiefly ring bark>/

#81. <periderm> course/

☐ ☐ 1. straight/

☐ ☐ 2. undulating/

☐ ☐ 3. irregular <without defined pattern>/

#82. <periderm colour; determined mainly by phellem, best to establish in T.S. of dry, unstained material>/

colour ....

....

#83. <periderm> penetrated by <presence of other tissues in periderm, best established in intact bark under low magnification>/

☐ ☐ 1. fibres/

☐ ☐ 2. sclereids/

☐ ☐ 3. fibre-sclereids <all transitional states between fibres and sclereids>/

☐ ☐ 4. secretory structures <laticifers, secretory ducts, secretory tubes, etc.; rare>/

#84. <type of> phellem <development of intercellular spaces>/

☐ ☐ 1. compact/

☐ ☐ 2. aerenchymatous <rare>/

#85. lignified cells (phelloid/phellem) <walls stain red with safranin O>/

☐ ☐ 1. present/

☐ ☐ 2. absent/

#86. phellem <width; best established in T.S. of dried, unsectioned material>/

....mm wide/

#87. <phellem> stratification/

☐ ☐ 1. present/

☐ ☐ 2. absent/ → #89

#88. <elements and pattern of stratification>/

....

....

#89. <predominant shape of> phellem cells with/

☐ ☐ 1. tangential diameter greater than radial diameter <tangentially elongate>/

☐ ☐ 2. tangential diameter less than radial diameter <radially elongate>/

☐ ☐ 3. tangential diameter equal to radial diameter <square>/

#90 conspicuous radially enlarged phellem cells <presence or absence>/

☐ ☐ 1. present/

☐ ☐ 2. absent/

#91. lignified cells (phellem/phelloid) with <shape in T.S.>/

☐ ☐ 1. tangential diameter greater than radial diameter <tangentially elongate>/

☐ ☐ 2. tangential diameter less than radial diameter <radially elongate>/

☐ ☐ 3. tangential diameter equal to radial diameter <square>/

☐ ☐ 4. more or less isodiametric/

☐ ☐ 5. irregular shape/

#92. pattern of cell-wall thickening of lignified cells (phellem/phelloid)>/

☐ ☐ 1. all walls evenly thickened/

☐ ☐ 2. all walls irregularly thickened/

☐ ☐ 3. only outer and inner tangential walls evenly thickened/

☐ ☐ 4. only radial walls thickened/

☐ ☐ 5. U-shaped thickening <inner tangential wall is thickened together with adjoining parts of the radial wall> with clear cell lumen/

☐ ☐ 6. U-shaped thickening <inner tangential wall is thickened together with adjoining parts of the radial wall> with obscure cell lumen/

☐ ☐ 7. reversely U-shaped thickening <outer tangential wall is thickened together with adjoining parts of radial wall>/

☐ ☐ 8. inner tangential wall dentately thickened <rare>/

☐ ☐ 9. outer tangential wall dentately thickened <rare>/

☐ ☐ 10. walls perforated <rare; pit transformed into large air-filled holes>/

#93. thickened cells wall <pitting>/

☐ ☐ 1. indistinctly pitted/

☐ ☐ 2. sparsely pitted;

☐ ☐ 3. distinctly pitted/

#94. <phellem cells> tanniniferous cells (not notably enlarged)/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#95. idioblasts <in the case of sclereids, these should differ markedly from phelloids/lignified phellem cells>/

☐ ☐ 1. present <rare>/

☐ ☐ 2. absent/ → #98

#96. composed of <idioblast type>/

☐ ☐ 1. sclereids/

☐ ☐ 2. crystalliferous cells/

☐ ☐ 3. secretory structures/

#97. <attributes of idioblasts, e.g. distribution, associated with lenticels, etc.>/

....

....

#98. calcium oxalate crystals <phellem>/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#99. phelloderm <best established in oldest phelloderm>/

☐ ☐ 1. well developed <more than 3 layers>/

☐ ☐ 2. absent or very poorly developed/ → #110

#100. stratification <of phelloderm>/

☐ ☐ 1. present/

☐ ☐ 2. absent/ → #102

#101. <stratification pattern>/

....

....

#102. phelloderm <type; sclereids absent or present and pattern of distribution>/

☐ ☐ 1. parenchymatous <sclereids absent>/

☐ ☐ 2. partially sclerified, sclereids predominantly solitary/

☐ ☐ 3. partially sclerified, sclereids irregularly scattered;

☐ ☐ 4. partially sclerified, inner layers more or less forming a sclerenchyma ring/

☐ ☐ 5. sclerified, sclereids assembled in irregularly shaped groups/

☐ ☐ 6. sclerified (at least inner portion), sclereids forming a sclerenchymatous ring <sclereid ring>/

#103. parenchyma cells <shape in phelloderm; best established near the phellogen in T.S.>/

☐ ☐ 1. more-or-less isodiametric/

☐ ☐ 2. mainly with tangential diameter greater than radial diameter <tangentially elongate>/

☐ ☐ 3. mainly with tangential diameter less than radial diameter <radially elongate>/

☐ ☐ 4. mainly with tangential diameter equal to radial diameter <square>/

#104. <sclereid type, e.g. spheroidal, vesiculose, vermiform, fusiform, filiform, polymorphic (for a sub-division of this category see Rao & Bhupal 1973)>/

sclereids ....

....

#105. walls <thickening of sclereids>/

☐ ☐ 1. all evenly thickened/

☐ ☐ 2. with U-shaped thickening <inner tangential wall is thickened together with adjoining parts of the radial wall>/

☐ ☐ 3. with reversely U-shaped thickening <outer tangential wall is thickened together with adjoining parts of radial wall>/

#106. tanniniferous <phelloderm> cells/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#107. calcium oxalate crystals <phelloderm>/

☐ ☐ 1. abundant/

☐ ☐ 2. sparse/

☐ ☐ 3. absent/

#108. <calcium oxalate crystals, e.g. type, variability, distribution patterns>/

....

....

#109. chloroplasts <best established in living samples of phelloderm>/

☐ ☐ 1. present/

☐ ☐ 2. absent/

#110. lenticels <frequently; established macroscopically>/

☐ ☐ 1. numerous/

☐ ☐ 2. scarce/

☐ ☐ 3. arranged in transverse rows/

Cortex

#112. cortex <present in young stems, persistent>/

☐ ☐ 1. present, forming a distinct zone in mature bark/ → #113

☐ ☐ 2. absent in mature bark/

#113. <cortex attributes; scattered sclereids, presence of crystals, tanniniferous, presence of secretory structures>/

....

....

CHAPTER 3

CONCISE REVIEW OF THE SUPRAGENERIC CLASSIFICATION OF THE EUPHORBIACEAE

3.1 INTRODUCTION

The family Euphorbiaceae is enormous in size and there is a great deal of diversity in its morphology, ecology and biochemistry. The family is thus, grossly heterogeneous. As a result, Meeuse (1990) claims that several authors have complained about the lack of unifying characters within the family. This has caused the position of this family in the general scheme of classification to be debatable.

Due to its enormous size and immense diversity, the classification of the Euphorbiaceae remains controversial. Mabberley (1987) writes that according to Airy-Shaw 'the classification of the family needs drastic overhauling', and the limits are unclear, a number of peripheral genera have been segregated as distinct families (Table 2). The controversy arises from differences within the family in, for instance, inflorescence type, floral morphology, pollen morphology, pollination, ovule structure, embryology, chromosome number, wood anatomy and alkaloids. Consequently Pax (1924), Cronquist (1981) and Mabberley (1989), amongst others, have treated the family as polyphyletic.

In the 12th edition of *Engler's Syllabus der Planzenfamilien*, the Euphorbiaceae are included in the order Geraniales (Melchior 1964). Takhtajan (1980), however, allies them with the Malvales in the subclass Dilleniidae. In his *An Integrated System of*

Classification of Flowering Plants, Cronquist (1981) places them in the order Euphorbiales under subclass Rosidae. Thorne (1983), classifies the Euphorbiaceae under subclass Dicotyledoneae (Annonidae), superorder Malviflorae and order Euphorbiales. Dahlgren (1983), places the Euphorbiaceae under the subclass Malviflorae in the order Euphorbiales. He contends that there is now general agreement that Euphorbiales are related to Malvales. Croizat (1973) and Hutchinson (1973) place one family, the Euphorbiaceae, under the Euphorbiales, whereas Stebbins (1974), Takhtajan (1980), Cronquist (1981), Dahlgren (1983) and Thorne (1983) include four to six families under the Euphorbiales. Webster (1987), maintains that the Euphorbiales are best construed as containing a single major family, the Euphorbiaceae, as suggested by Hutchinson (1973) and Croizat (1973).

3.2 CLASSIFICATION

Adrien de Jussieu (1824) was the first to circumscribe and define the Euphorbiaceae. He subdivided the family into six well defined sections on the basis of ovule number, stamen insertion, presence of petals and type of inflorescence. He, surprisingly, did not formally name his six sections. These were named and given formal status as tribes by subsequent researchers such as Dumortier (1829), Bartling (1830) and Spach (1834). They named them Buxeae, Phyllantheae, Ricineae, Acalypheae, Hippomaneae and Euphorbieae.

Webster (1987) attests that the first and the last complete monograph of the Euphorbiaceae is that of Boissier (1862) and Mueller (1866) in A.P. de Candolle's *Prodromus Systematis Naturalis Regni Vegetabilis*. Boissier (1862) defined and circumscribed the tribe Euphorbieae on the basis of a judicious choice of characters. Mueller (1866) recognised ten tribes. In exclusion of the tribe Buxeae, which was one of the six tribes de Jussieu (1824) had delimited, he added five, namely Caletieae, Ricinocarpeae, Ampereae, Bridelieae and Dalechampieae. These tribes he circumscribed and defined on the basis of ovule number, aestivation of calyx, orientation of anthers in the bud, presence or absence of an involucre or petals and position of insertion of stamens. He has been challenged and criticized by subsequent workers for his choice of characters. These characters have been claimed to be of insignificant diagnostic value in the infrafamial taxonomy of the Euphorbiaceae.

Pax (1910), who later worked with Käthie Hoffmann, initiated a series of 17 monographic treatments of the Euphorbiaceae. This monumental work culminated in the last detailed infrafamilial classification of the group (Pax & Hoffmann 1931). Since this classification of the Euphorbiaceae, at least three notably broad classifications of the family were proposed; Hurusawa (1954), Hutchinson (1969) and Webster (1975).

Hurusawa (1954) dismembered the Euphorbiaceae into four families, namely Antidesmataceae, Euphorbiaceae, Porantheraceae and Ricinocarpaceae. On the basis of the ovule number per locule, he circumscribed seven subfamilies, namely three biovulate subfamilies, Bridelioideae, Antidesmatiodeae and Phyllanthoideae, and four uniovulate subfamilies, Euphorbioideae, Acalyphoideae, Crotonoideae and Sapioideae. Hurusawa (1954) also delimited five new tribes namely, Epiprineae, Aleuritideae, Hureae, Drypeteae and Bischofieae.

In discrediting Hurusawa's classification, Webster (1987) states that Hurusawa's four families really represent the four subfamilies of Pax raised to family rank, and as such they do not indicate any novelty of classification. He further writes that, to the best of his knowledge, none of Hurusawa's proposed segregate families have been accepted.

Hutchinson (1969) introduced an original classification of the Euphorbiaceae that discarded subfamilies, instead he proposed 40 tribes to which genera were assigned. He posited that the tribes he proposed were arranged, as far as is possible in a phylogenetic sequence. Further, he did not favour the separation of any part of the Euphorbiaceae as segregate families, because he considered the family to be no less homogeneous than any other. His classification system of the Euphorbiaceae, as outlined in Table 3, contains 23 out of the 27 genera relevant to this study.

In evaluating Hutchinson's classification of the Euphorbiaceae against his own, Webster (1987) writes that, it is notable that 11 of the 40 Hutchinsonian tribes contain genera belonging to at least three different tribes. Webster holds that Hutchinson's classification is retrograde in some respects. Partly due to his reliance on *Gestalt* of habit and gross floral morphology, without seeking correlations among anatomical, cytological or palynological characters. Finally, his insistence on using a rank between family and genus would in itself result in considerable distortion of relationships compared to a more hierarchical system. None the less, Hutchinson's classification does display the virtue of awarding tribal rank to phylogenetically isolated genera such as *Uapaca*.

The most recent broad classification of the Euphorbiaceae is by Webster (1975, 1987). He proposed a new classification of the family into five subfamilies: Phyllanthoideae, Oldfieldioideae, Acalyphoideae, Crotonoideae and Euphorbioideae, with 52 tribes and 52 subtribes. He claims that his system of infrafamilial relationships in the Euphorbiaceae is compatible with data gleaned from fields such as wood anatomy, cytology and biochemistry. He further states that several years of study of the genera have now culminated in a new classification of the Euphorbiaceae which appears to better reflect phylogenetic relationships than the older systems of Mueller Argoviensis (1866), Pax & Hoffman (1931), Hurusawa (1954) or Hutchinson (1969).

Punt (1987), working on pollen morphology in the Euphorbiaceae, remarked that the classification of Webster (1975) 'represents the best we have today'. Mabberley (1987) in his *The Plant Book* uses Webster's classification 'as a recent arrangement within the family'. Unless otherwise indicated, Webster's classification as outlined in Table 4, has been used as the basis for the present study.

The five new tribes, namely Epiprineae, Aleuritideae, Hureae, Drypeteae and Bischofieae, that were delimited by Hurusawa (1954), were retained by Webster (1975, 1987) in Table 4. Webster (1975, 1987) also recognised and retained most of the tribes that were circumscribed by Hutchinson (1969) in Table 3. The segregate families and their type genera, except the Pandaceae in Table 2, Webster (1975, 1987) has arranged under different subfamilies, tribes and subtribes in Table 4. Their genera are indicated by '†' in Table 4. About the Pandaceae, Webster (1987) concluded that '... despite the arguments of Forman (1966, 1968, 1971), the evidence to support the status of the Pandaceae as a separate family is very weak, and rests more on our ignorance than on our knowledge. The Pandaceae is very tentatively accepted ... as the only other family of Euphorbiales, with the understanding that future studies may demonstrate that it is better treated as a group within the Euphorbiaceae'.

CHAPTER 4

SOUTHERN AFRICAN EUPHORBIACEAE

4.1 INTRODUCTION

The family Euphorbiaceae is well represented in southern Africa. Brown *et al.* (1925) in Flora Capensis — being a systematic description of the plants of the Cape Colony, Caffraria, Port Natal and neighbouring territories — described the family Euphorbiaceae. They divided the family into four tribes, Euphorbieae, Buxeae, Phyllantheae and Crotoneae. Included in these tribes were 40 genera with 350 species.

Subsequent authors have recorded members of the Euphorbiaceae from all countries south of the Kunene, Okavango and Zambezi Rivers (southern Africa). That is to say Botswana, Lesotho, Mozambique, Namibia, South Africa including all Black homelands, Swaziland and Zimbabwe (Maclean 1993). As to trees, Palmer & Pitman (1972) listed 29 genera that contain 60 species for the Flora of Southern Africa (FSA) region (Botswana, Lesotho, Namibia, South Africa including all Black homelands and Swaziland). For the same region (FSA), Dyer (1975) reported 48 genera containing 394 species. Gibbs Russell *et al.* (1987) listed 50 genera boasting 518 species. Recently, 468 species representing 51 genera were documented for the FSA region (Arnold & De Wet 1993). For southern Africa, Coates Palgrave (1981) recorded 94 species that belong to 36 tree genera. See Table 5 in Part 2.

4.2 WOODY SPECIES

Most of the woody species researched in this study, also occur outside the Republic of South Africa. However, the following woody species that were studied are endemic to South Africa: those belonging to endemic genera are marked with an asterisk (Coates Palgrave, 1981), common names in brackets:

- *Acalypha sonderiana* (Thorny false-nettle, Doringvalsnetel)

- *Erythrococca berberidae* (Prickly red berry, Dorinkiebessie, Doringrooibessie)

- *Heywoodia lucens* (Stink ebony, Cape ebony, Black ebony, Stinkebbehout, Ebbehout, Swartebbehout)

- **Hyaenanche globosa* (Hyaena poison, Wolwegifboom, Wolweboontjie, Wolwegif, Boesmansgif, Gifboom, Wolweboom)

- **Lachnostylis bilocularis* (Rock coalwood, Klipkoolhout, Kliphout, Klipboom)

- **L. hirta* (Coalwood, Koolhout)

- **Micrococca capensis* (Common bead-string, Gewone Kralesnoer)

- *Phyllanthus cedrifolius* (Feather-leaved pheasant-berry, Forest potato bush, Bastard potato bush, Bosaartapelbos, Basteraartapelbos, Veerblaarfisantebessie)

- *Suregada africana* (Common canary-berry, Gewone kanariebessie)

- *Synadenium cupulare* (Dead-man's tree, Crying tree, Gifboom, Dooiemansboom)

4.3 SUCCULENTS

Succulents and spiny forms are presumably restricted to subfamily Euphorbioideae (Meeuse 1990). Because of their abundance and striking cactus-like appearance, species of *Euphorbia* are the best known succulent members. They are, however, not in any way related to the cactus family (Palmer & Pitman 1972). A simple test tells them apart: a pin prick on the euphorbia stem produces a trickle of white, milky latex, often poisonous, whereas a cut cactus stem is nearly always bright green and juicy (a few members do contain milky latex!). Far from being poisonous, delightful recipes for delicacies, such as 'cactus pear candy' and 'saguaro jam', are popular in some western American homes (Court 1981).

Croizat (1965) contends that these succulent euphorbias are primary rooted in their own full right in a sector of the map of southern Africa. Coates Palgrave (1981) cites the following tree species of *Euphorbia* as endemic to southern Africa:

- *Euphorbia angularis*

- *E. confinalis* (Lebombo euphorbia, Lebombo-naboom)

- *E. cooperi* (Transvaal candelabra tree, Transvaalse Kandelaarnaboom)

- *E. curvirama* (Cape candelabra tree, Kaapse kandelaarnaboom)

- *E. eduardoi* (Kaoko euphorbia, Kaokonaboom)

- *E. evansii* (Lowveld euphorbia, Small-toothed euphorbia, Laeveldnaboom, Kleintand-naboom)

- *E. excelsa* (Olifants River euphorbia, Olifantsriviernaboom)

- *E. fortissima* (Zambezi candelabra tree, Zambezi Kandelaarnaboom)

- *E. grandidens* (Large toothed-euphorbia, Valley-bush euphorbia, Groottandnaboom, Valleibosnaboom)

- *E. halipedicola* (Zig-zag candelabra tree)

- *E. ingens* (Candelabra tree, Cactus euphorbia, Common tree euphorbia, Gewone naboom, Gewone melkboom, Naboom, Noorsdoring, Kankerbos)

- *E. keithii* (Swazi euphorbia, Swazinaboom)

- *E. lividiflora* (Red-flowered euphorbia)

- *E. sekukuniensis* (Sekukuni euphorbia, Sekukuni-naboom, Sekoekoensnaboom)

- *E. tetragona* (Honey euphorbia, 'Map tree', Heuningnaboom, Grootnoorsdoring, Noorsdoring)

- *E. tirucalli* (Rubber euphorbia, rubber tree, Kraalnaboom, Kraalmelkbos)

- *E. triangularis* (River euphorbia, Chandelier tree, Riviernaboom, Noorsdoring, Driehoekmelkbos)

- *E. zoutpansbergensis* (Soutpansberg euphorbia, Soutpansbergnaboom)

The succulent *Euphorbia* species are anatomically problematic. The boundaries of the different bark tissues of spiny succulents, such as E. cooperi, E. ingens and *E. tirucalli*, are not as clearly dermarcated as in the few woody *Euphorbia* species, such as *E. espinosa*. As a result this group of the Euphorbiaceae warrants further investigation to resolve their bark anatomy fully.

4.4 MEDICINAL OR ECONOMIC USES OF SELECTED SPECIES

Vegetation is one of the most important natural resources. From time immemorial humankind has been making use of plants for food, shelter, fuel, medicine and for other purposes as deemed fit. The following species (for all of which the bark anatomy was studied), where they occur, are used by local residents for their survival, and their bark usages are printed in bold:

- *Acalypha glabrata* var. *pilosior* (Forest false-nettle, Bosvalsnetel). In the northern Transvaal the young twigs are eaten as spinach. In Zululand the wood is used for fencing cattle kraals. Fish traps are also made of the tough elastic branchlets (Palmer & Pitman 1972).

- *Andrachne ovalis* (Bastard lightning bush, Basterbliksembos). Famous for its roots for their power to kill insects and drive snakes away. An infusion of the root is used as a shampoo to kill lice. The Zulu use the plant as a snake-bite remedy, as an emetic to treat chest complaints and when burnt and sniffed as a headache cure (Watt & Breyer-Brandwijk 1962; Palmer & Pitman 1972).

- *Androstachys johnsonii* (Lebombo ironwood, Lebombo-ysterhout). The wood is valuable, very hard, fine-grained, durable and almost termite-proof. It is used as railway sleepers, fence posts, for flooring and joinery (Palmer & Pitman 1972; Coates Palgrave 1981).

- *Antidesma venosum* (Tassel-berry, Voëlsitboom, Tosselbessie). The fruit is edible (Watt & Breyer-Brandwijk 1962). In African medicine an infusion of the root is used to bathe the body to ease pain and it is also a constituent of a mixture believed to ensure fertility (Palmer & Pitman 1972; Coates Palgrave 1981),

- *Bridelia micrantha* (Mitzeerie, Mitserie, Bruinstinkhout). The wood makes good flooring, furniture and fence poles. It also has been used for panelling (Palmer & Pitman 1972). The root is said to have purgative properties. It is taken to relieve stomach pains and possibly to treat gastric ulcers (Coates Palgrave 1981).

- *Cavacoa aurea* (Natal hickory, Natal-okkerneut). The tree yields good sticks. Zulus drink an infusion of the boiled roots to relieve pain and to reduce fever. They inhale the steam to relieve sinusitis (Palmer & Pitman 1972; Coates Palgrave 1981).

- *Cleistanthus schlecteri* (False Tamboti, Bastertambotie). It is used in hut-building, for particularly good sticks and as fuel. In Zululand it is considered one of the hardest of the local woods (Palmer & Pitman 1972).

- *Croton gratissimus* (Lavender croton, Laventelkoorsbessie). The bark is used for dropsy, indigestion, pleurisy and uterine disorders (Watt & Breyer-Brandwijk 1962). The Zulu use the leaves as a cure for insomnia. Children make catapults of the twigs (Palmer & Pitman 1972). **Charred and powdered bark is used to treat bleeding gums** (Coates Palgrave 1981).

- *Croton megalobotrys* (Fever-bark tree, Koorsboom). Malarial remedy long known to Africans and early pioneers (see Chapter 1). **Seeds and bark have purgative properties and are widely used by Africans** (Palmer & Pitman 1972; Coates Palgrave 1981). **Powdered bark is taken in porridge to cause abortion and to treat swollen testicles in men and infertility in women** (Gelfand *et al.* 1985).

- *Croton sylvaticus* (Woodland croton, Fever tree, Boskoorsbessie). **Powdered bark is a remedy for gall-sickness in cattle** (Watt & Breyer-Brandwijk 1962). **Bark is used as a poultice to treat rheumatism and also as a fish poison** (Palmer & Pitman 1972; Coates Palgrave 1981).

- *Drypetes natalensis* (Natal ironplum, Natal-ysterpruim). The wood is used for roofing material, lathes, sticks and fuel (Palmer & Pitman 1972).

- *Euphorbia ingens* (Cactus euphorbia, Common tree euphorbia, Naboom, Gewone melkboom). Latex in porridge is taken to treat bronchitis, to serve as a purgative or as an emetic (Gelfand *et al.* 1985).

  A drop of latex in the eye can cause severe inflammation and temporary or permanent blindness. Exposure of the skin or buccal mucosa to the latex results in the vesicles and ulcers. The latex also has piscicidal properties. Wefts of grass soaked in latex are bound to stones and dropped into pools by tribesmen living along the Limpopo River. After about 15 minutes stupified fish are said to float to the surface where they can be harvested (Kellerman *et al.* 1990).

- *Euphorbia tirucalli* (Rubber hedge euphorbia, Kraalnaboom). Few drops of latex in a glass of milk serve as an antidote to poison (Gelfand *et al.* 1985).

- *Flueggea virosa* (White-berry bush, Witbessiebos). Leafy branches are used as brooms. The tree is said to be an indicator of underground water (Palmer & Pitman 1972). **The tannin in the bark provides a treatment for diarrhoea and pneumonia** (Coates Palgrave 1981).

- *Heywoodia lucens*. A professional violin-maker in South Africa successfully used the wood for the chinrest, fingerboard, frog pegs and tail pieces of a violin (Palmer & Pitman 1972).

- *Hyaenanche globosa.* Leaves, seeds and stems contain hyaenanchin, which acts like strychnine in changing the nervous condition in the brain and spinal cord and producing muscular convulsions (Watt & Breyer-Brandwijk 1962). Bushmen extracted poison from the fruits for their deadly arrow poison (Coates Palgrave 1981).

- *Lachnostylis hirta.* The wood is good fuel and makes excellent charcoal, hence the name 'coalwood' (Palmer & Pitman 1972).

- *Macaranga capensis* (Wildpoplar, Wildepopulier). The wood is suitable for boxes and planking. It is fire-resistant (Palmer & Pitman 1972; Coates Palgrave 1981).

- *Margaritaria discoidea* (Common pheasant-berry, Gewone fisantebessie, Egossa red peer, Egossarooipeer). **A decoction of the tannin in the bark is taken to relieve pains after childbirth. Ashes from the burnt bark mixed with salt and palm oil, apparently produce a burning sensation and are applied to relieve lumbar pains** (Coates Palgrave 1981).

- *Pseudolachnostylis maprounefolia* (Kudu-berry, Koedoebessie). A sacred tree in Malawi (Palmer & Pitman 1972). Africans inhale smoke from burning roots to treat pneumonia, and they use a **bark extract to remedy diarrhoea** (Coates Palgrave 1981). **Infusion of bark is taken to treat nausea and dizziness** (Gelfand *et al.* 1985).

- *Sapium integerrimum* (Duikery-berry, Duikerbessie). The water in which the roots have been boiled makes a mouthwash to ease toothache. The wood is used for houseand hut-building and makes beautiful furniture (Palmer & Pitman 1972). In the past ink was made from the fruits, and they have also been used in tanning (Coates Palgrave 1981).

- *Spirostachys africana* (Cape sandalwood, Tambotie, Jumping-bean tree). **The dry bark is used as an embrocation to cure rash in babies** (Palmer & Pitman 1972). The effects of wood on insects are so unpleasant to them that pieces of wood are placed among clothing as a repellent. The heart wood is almost indestructible and samples in a very good state of preservation were taken from the Zimbabwe Ruins for carbon-dating. They were reported as being between 1240 and 1530 years old (Coates Palgrave 1981). Tambotie wood is also used for furniture. **The Tsonga use the powdered bark, in very small doses, as a purgative. The Sotho use a decoction of the bark as an emetic, and the bark is used in Zimbabwe as a fish poison** (Watt & Breyer-Brandwijk 1962).

CHAPTER 5

BARK ANATOMICAL DESCRIPTIONS

5.1 INTRODUCTION

In this chapter the taxa studied are arranged alphabetically. Scientific names and author(s) citations are followed by numbers, in brackets, of the FAA-preserved samples used. A representative diagram of the bark (in T.S.) is supplied for each taxon in Part 2 of this study. The bark anatomical characters described include axial phloem parenchyma, phloem rays, sclerenchyma, dilatation tissue, calcium oxalate crystals, tanniniferous cells, secretory structures, mature periderm and cortex. The descriptions were processed by use of the DELTA computer programme, and were subsequently edited for brevity, clarity and consistency. Selected characters are summarized for each taxon in Table 6 (Part 2 of this study).

Brief descriptions of succulent *Euphorbia cooperi, E. ingens* and *E. tirucalli* and woody *Uapaca kirkiana* and *U. sansibarica* are presented, because it was not possible to investigate some of the characters which were considered in this study. Due to the very nature and structure of the above-mentioned bark samples, it was difficult to cut decent and complete sections of the material.

Particularly significant characters are highlighted in bold.

5.2 *Acalypha glabrata* Thunb. var. *glabrata* (Kuntze) Prain (1568, 1569, 1607); Figure 2.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements; cells axially elongated or more or less isodiametric. Tanniniferous cells absent. Calcium oxalate crystals styloids, abundant and randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular; cells square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells with green-stained contents in which crystals are embedded. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals styloids and prisms, abundant, randomly distributed in dark-coloured matrix (cytoplasm).

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids**; forming irregular compact groups, sclereid shape spheroidal, walls more-or-less even, lumen round to slit-like.

DILATATION TISSUE. Dilatation tissue well developed. Derived from phloem parenchyma and rays; type irregular ("diffuse" type) or rays regularly dilated wedge-shaped. Well defined dilatation meristem absent. Sclerenchyma absent. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, poorly developed, comprising weakly lignified fibres and cellulosic fibres. Tanniniferous cells absent. Calcium oxalate crystals styloids and prisms, abundant or sparse, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals usually **styloids**, occasionally **prisms**, rarely **microprisms**, abundant, located mainly in axial phloem parenchyma, ray cells, phelloderm and cortex, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent.**

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent, all cell-walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells more or less isodiametric or mainly with tangential diameter equal to radial diameter, walls all evenly thickened. Tanniniferous cells absent. Calcium oxalate crystals styloids and prisms, abundant and randomly distributed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark, with prisms and acicular crystals randomly dispersed.

5.3 *Acalypha glabrata* Thunb. var. *pilosior* (Kuntze) Prain (1592); Figure 3.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma in weak tangential lines, consisting of more or less isodiametric cells. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant in short tangential rows and occurring singly.

PHLOEM RAYS. Phloem rays heterocellular, cells square and/or upright; 1—3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) **absent**.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; type irregular ('diffuse' type). Well defined dilatation meristem absent. Sclerenchyma absent. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, poorly developed: thick-walled lignified fibre-sclereids in sparsely dispersed clusters. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse and randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **druses**, abundant and located mainly in axial phloem parenchyma, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands present, remaining parenchymatous and randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification present, thin-walled layers alternating with lignified layers; lignified cells with tangential diameter equal to radial diameter; cell-walls U-shaped thickened with distinct cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; druses present, sparsely dispersed.

5.4 *Acalypha sonderiana* Muell.Arg (1683); Figure 4.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, consisting of axially elongated cells. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular; cells square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma occasionally lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant and radially dispersed in dark-coloured matrix (cytoplasm).

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising usually **sclereids**, rarely **fibre-sclereids**, forming staggered plates, tangentially oriented; fibre-sclereids irregular in shape;sclereid shape spheroidal or rectangular, walls more-or-less even, lumen round, elongate, slit-like or irregular.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; type irregular ('diffuse' type). Well defined dilatation meristem absent.

Sclerenchyma present, secondarily derived sclereids spheroidal, mainly associated with aggregates of primary sclerenchyma. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, poorly developed, comprising isolated groups of cellulosic fibres with relatively small diameters and cell-walls not distinctly polylammelate. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms** and **druses,** abundant and located mainly in axial phloem parenchyma, ray cells, and dilatation tissue; not encased in sclerotic elements or encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified and nearly always associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells **absent.**

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification present, unlignified layers alternate with lignified layers; cell-walls evenly or reversely U-shaped thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm very poorly developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells absent. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; druses present, randomly scattered.

5.5 *Andrachne ovalis* (Sond.) Muell.Arg. (1651); Figure 5.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, consisting of axially elongated cells. Tanniniferous cells sparse. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular; cells square and/or upright; 1—3-seriate, course more-or-less straight; portion of rays traversing or adjacent to sclerenchyma remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells sparse. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibre-sclereids** and **sclereids**; forming irregular compact groups; fibre-sclereids rectangular or pyriform; sclereid shape spheroidal, square, triangular or irregular, walls more-or-less even, lumen irregular, linear or round.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays, irregular ('diffuse' type). Well-defined dilatation meristem absent. Sclerenchyma present; secondarily derived sclereids spheroidal, irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells sparse. Calcium oxalate crystals absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **absent**.

TANNINIFEROUS CELLS. Tanniniferous cells sparsely dispersed in phloem parenchyma, phloem rays, and in dilatation tissue.

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.6 *Androstachys johnsonii* Prain (1599, 1600); Figure 6.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, consisting of more or less isodiametric cells. Tanniniferous cells abundant. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular; cells square and/or upright; **exclusively uniseriate**, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin to thick-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres** and **sclereids**; forming staggered lenticular plates or arranged in discontinuous tangential bands; fibres non-septate, walls very thick; sclereid shape spheroidal, walls more or less even, lumen round, rectangular, angular or linear.

DILATATION TISSUE. Dilatation tissue **poorly developed or absent.**

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in sclerenchyma, associated with clusters of sclereids and encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified and associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma adjacent to sclerenchyma bands.

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter or irregularly shaped, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed. Multiple periderms present.

CORTEX. Cortex **absent** in mature bark.

5.7 *Antidesma venosum* E.Mey. ex Tul. (1490, 1637, 5931); Figure 7

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, consisting of axially elongated cells and occasionally more or less isodiametric cells. Tanniniferous cells sparse. Calcium oxalate crystals prisms, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular; cells hexagonal/isodiametric; 1—3-seriate, **very occasionally up to 5-seriate**, course more or less straight; portion of rays traversing or adjacent to sclerenchyma remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms and druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising nearly always **fibres, rarely fibre-sclereids and sclereids** associated with fibres; forming loose tangential groups or irregular compact groups; fibres non-septate, walls nearly always very thick; fibre-sclereids axially elongated and rectangular; sclereid shape rectangular, walls more or less even, lumen round, linear, rectangular, square or elliptical.

DILATATION TISSUE. Dilatation tissue **poorly developed or absent.**

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in crystalliferous cells, wreathing the sclerenchyma and associated with fibres, druses not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma and phloem rays.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter and rarely tangential diameter equal to radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.8 *Bridelia cathartica* Bertol. f. (1731); Figure 8.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells sparse. Calcium oxalate crystals prisms, very sparse.

PHLOEM RAYS. Phloem rays heterocellular, cells hexagonal/isodiametric; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse, randomly dispersed.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **lignified fibres** and very occasionally **gelatinous fibres**, arranged in discontinuous tangential bands, non-septate, walls nearly always very thick.

DILATATION TISSUE. Dilatation tissue **poorly developed or absent**.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms** and **druses**, abundant, located mainly in ray cells and sclerenchyma, not encased in sclerotic elements and usually associated with fibres. Axially arranged chambered crystalliferous strands present, occasionally remaining parenchymatous and associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma and in rays, nearly always forming tangential rows associated with sclerenchyma.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter or tangential diameter equal to radial diameter, all cell- walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or poorly developed.

CORTEX. Cortex **absent** in mature bark.

5.9 *Bridelia micrantha* (Hochst.) Baill. (1491, 1493, 1799, 1588); Figure 9.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells more-or-less isodiametric. Tanniniferous cells abundant. Calcium oxalate crystals prisms and druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells hexagonal/isodiametric; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising usually **lignified fibres**, occasionally **gelatinous fibres** and very occasionally **sclereids**; arranged in discontinuous tangential bands; fibres non-septate, walls thin to thick; sclereid shape square, rectangular or spheroidal, walls more-or-less even, lumen round, square or rectangular.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; type continuous forming a broad zone (pseudocortex). Well-defined dilatation meristem absent. Sclerenchyma present, very sparse, secondarily derived sclereids rectangular or spheroidal, irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms** and **druses**, sparse, located mainly in axial phloem parenchyma, ray cells, sclerenchyma and in crystalliferous cells, wreathing the sclerenchyma; druses not encased in sclerotic elements, prisms encased within secondarily formed sclereids in the dilatation zone or encased within crystalliferous strands associated with fibres. Axially arranged chambered crystalliferous strands present, occasionally sclerified and associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma, phloem rays, dilatation tissue and phelloderm.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells often with tangential diameter greater than radial diameter, very occasionally tangential diameter less than radial diameter, and occasionally tangential diameter equal to radial diameter, all walls evenly thickened; conspicuous radially enlarged phellem cells absent, all walls evenly thickened. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm usually absent or poorly developed, very occasionally well developed. Stratification absent. Phelloderm parenchymatous, cells more or less isodiametric. Tanniniferous cells always abundant. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.10 *Bridelia mollis* Hutch. (1572); Figure 10.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells more or less isodiametric. Tanniniferous cells abundant. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, hexagonal/isodiametric; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma occasionally lignified; aggregate rays absent. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising nearly always **lignified fibres** and very rarely **gelatinous fibres**, forming nearly always, almost continuous concentric rings, non-septate, walls thin to thick.

DILATATION TISSUE. Dilatation tissue **poorly developed or absent**.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located in sclerified axial chambered crystalliferous strands, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in rays and outer phloem parenchyma.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, all walls evenly thickened; conspicuous radially enlarged phellem cells absent, Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.11 *Cavacoa aurea* (Cavaco) J. Leonard (1624, 1677, 1695); Figure 11.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells more-or-less isodiametric. Tanniniferous cells abundant. Calcium oxalate crystals micro-prisms, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids**; forming storied plates or arranged in concentric discontinuous tangential bands; sclereid shape spheroidal or vesiculose, walls more-or-less even, lumen round, square, oval, rectangular or slit-like.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays, continuous forming a broad zone ('pseudocortex'). Well defined dilatation meristem absent. Sclerenchyma absent. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms and druses, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant and located mainly in ray cells and sclerenchyma, druses not encased in sclerotic elements and prisms often encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified and randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells abundant throughout the bark, except in periderm.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, cell-walls U-shaped thickened with distinct cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.12 *Cleistanthus schlecteri* (Pax) Hutch. (1686); Figure 12.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent. Distinct rows of collapsed sieve elements present.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; **usually 1—3-seriate and rarely larger rays 4—10-seriate**; course more or less straight; portion of rays traversing or adjacent to sclerenchyma rarely lignified, usually remaining parenchymatous; aggregate rays absent. Ray cells thin- walled and radially elongated. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising usually **fibres,** and rarely **fibre-sclereids**; forming storied plates or arranged in discontinuous tangential bands, often square to rectangular in outline; fibres non-septate, walls thin to thick.

DILATATION TISSUE. Dilatation tissue **poorly developed or absent**.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** sparse, located mainly in ray cells and crystalliferous cells wreathing the sclerenchyma, not encased in sclerotic elements, and associated with fibres. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent. Lignified cells with usually tangential diameter greater than radial diameter and rarely with tangential diameter less than radial diameter; cell-wall thickening U-shaped with distinct cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.13 *Clutia pulchella* L. (1582); Figure 13.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) **absent**.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; continuous forming a broad zone ('pseudocortex'). Well-defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, triangular, rectangular and large, irregularly dispersed as lens-shaped clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **absent**.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter. Lignified cells with tangential diameter greater than radial diameter; cell-walls reversely U-shape thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.14 *Croton gratissimus* Burch. (1567); Figure 14.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres and sclereids**; forming loose tangential groups, arranged in discontinuous tangential bands or forming almost continuous concentric rings; fibres non-septate, walls thin to thick; sclereid shape spheroidal, walls more or less even, lumen round, polygonal, linear or constricted.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; irregular ('diffuse' type) or continuous forming a broad zone ('pseudocortex'). Well defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells sparse. Calcium oxalate crystals druses, sparse, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in ray cells, sclerenchyma, and dilatation tissue, not encased in sclerotic elements and encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells, sparsely distributed in dilatation tissue and phelloderm.

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, cell-walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells more-or-less isodiametric or mainly with tangential diameter greater than radial diameter. Tanniniferous cells sparse. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent in mature bark.**

5.15 *Croton megalobotrys* Muell.Arg. (1728); Figure 15.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse randomly distributed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1-3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant, forming radial rows weakly alternating with diffuse parenchyma.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **lignified fibres, rarely cellulosic fibres and sclereids**; forming irregular compact groups, very rarely scattered with solitary elements. Fibres non-septate, walls thin to thick; sclereids spheroidal, walls more or less even, lumen usually round. Chambered crystalliferous strands present, lignified, forming the bulk of the sclerenchyma.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; rays irregularly dilated, wedge-shaped or continuous interdigitizing with the secondary phloem. Well-defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters or associated with aggregates of primary sclerenchyma. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells absent. Calcium oxalate crystals druses and prisms, sparse, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in axial phloem parenchyma, ray cells, sclerenchyma, dilatation tissue and phelloderm; druses, usually not encased or rarely encased in sclerotic elements, prisms encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells **absent.**

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm nearly always parenchymatous, rarely partially sclerified with sclereids forming deeper layers, cells mainly with tangential diameter greater than radial diameter; sclereids tangentially elongated, walls all evenly thickened. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.16 *Croton menyhartii* Pax (1610); Figure 16.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres and sclereids**; arranged in concentric discontinuous tangential bands, very rarely forming continuous concentric rings; fibres non-septate, walls thin to thick; sclereids spheroidal, walls more or less even, lumen round, polygonal, linear or constricted.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; irregular ('diffuse' type). Well defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters or associated with aggregates of primary sclerenchyma. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells sparse. Calcium oxalate crystals druses and prisms, abundant, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in ray cells and sclerenchyma, druses not encased in scleretic elements, prisms usually encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells sparse, randomly distributed in dilatation tissue and phelloderm.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. **Stratification present**, bands of cells with contents alternate with empty layers of cells. Phellem cells very often with tangential diameter less than radial diameter and often tangential diameter equal to radial diameter, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells sparse. Calcium oxalate crystals druses, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.17 *Croton pseudopulchellus* Pax (1602); Figure 17.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse, close to cambium.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth), present, comprising mainly **lignified fibres, rarely with few clusters of gelatinous fibres and sclereids;** arranged in concentric discontinuous tangential bands; fibres non-septate, walls thin to thick; sclereids spheroidal, walls more or less even, lumen round to linear.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; irregular ('diffuse' type) or continuous forming a broad zone ('pseudocortex'). Well defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal or fusiform, associated with aggregates of primary sclerenchyma or forming compact tangentially elongated clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells sparse. Calcium oxalate crystals prisms, sparse, randomly encased in sclereids.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in ray cells, sclerenchyma and dilatation tissue; druses not encased in sclerotic elements and prisms encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells sparse, randomly dispersed in dilatation tissue.

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact, lignified cells (phellem/phelloid) occasionally present. **Stratification present,** thin-walled layers alternate with thick-walled layers. Phellem cells mainly with tangential diameter greater than radial diameter, cell-wall thickening U-shaped with distinct cell lumen or U-shaped with obscure cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells absent. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.18 *Croton sylvaticus* Hochst. (1505, 4265, 1643, 1794, 1806, 1770); Figure 18.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells procumbent or hexagonal/isodiametric; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **lignified fibres and cellulosic fibres**; forming irregular compact groups or occasionally arranged in discontinuous tangential bands; fibres non-septate, walls thin to thick.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only or from phloem parenchyma and rays; irregular ('diffuse' type) or rays regularly dilated, wedge-shaped. Well defined dilatation meristem absent. Sclerenchyma present or absent. If present secondarily derived sclereids spheroidal, vesiculose or vermiform; irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, poorly developed, comprising cellulosic fibres with walls not polylamellate. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** sparse, located mainly in axial phloem parenchyma, ray cells and associated with fibres, not encased in scleretic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, in phelloderm and sparse, in cortex.

SECRETORY STRUCTURES. Secretory structures present, composed of secretory cells randomly dispersed in phloem parenchyma, dilatation tissue and cortex.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells usually with tangential diameter greater than radial diameter and rarely with tangential diameter equal to radial diameter, cell walls all evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm locally well developed.

Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells abundant. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark, with scattered secretory elements and tanniniferous cells.

5.19 *Drypetes arguta* (Muell.Arg.) Hutch. (1654, 1772); Figure 19.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified or remaining parenchymatous; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids and rarely fibre-sclereids**; arranged in discontinuous tangential bands; fibre-sclereids radially elongated; sclereids spheroidal, walls more or less even, lumen round to slit-like.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays, continuous and interdigitizing with the secondary phloem or rays regularly dilated, wedge-shaped. Well defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly scattered as idioblasts. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, well developed. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in ray cells, dilatation tissue, phelloderm and cortex; not encased in scleretic elements. Axially arranged chambered crystalliferous strands present, sclerified and randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact, lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, cell walls U-shape thickened with distinct cell lumen or U-shaped thickened with obscure cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter, walls evenly thickened. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; prisms present, randomly dispersed; sclereids present, arranged in small clusters of single or scattered groups.

5.20 *Drypetes gerrardii* Hutch. (1473, 1513 1581); Figure 20.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals prisms and druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres, fibre-sclereids, and sclereids;** forming irregular compact groups or arranged in discontinuous tangential bands; fibres non-septate, walls very thick; fibre-sclereids occasionally tangentially elongated; sclereids spheroidal, occasionally large and ovoid, walls more or less even, lumen round, elongated to slit-like.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; continuous forming a broad zone ('pseudocortex') or rays irregularly dilated, wedge-shaped. Well-defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, tangentially elongated, irregularly dispersed as clusters or mainly associated with aggregates of primary sclerenchyma. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, well developed. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant and druses, sparsely dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses**, abundant, located mainly in ray cells, sclerenchyma, dilatation tissue, phelloderm and cortex, not encased in sclerotic elements, or encased within sclereids and/or encased within secondarily formed sclereids in the dilatation zone. Axially arranged chambered crystalliferous strands present, sclerified or rarely remaining parenchymatous, associated with sclerenchyma or randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact, lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, cell walls U-shape thickened, with obscure cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter, walls all evenly thickened. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; prisms present, abundant; lignified cells present, small, scattered.

5.21 *Drypetes natalensis* (Harv.) Hutch. (1692, 1654); Figure 21.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres and sclereids**; arranged in discontinuous tangential bands; **fibres septate**, walls very thick; sclereids spheroidal, walls more-or-less even, lumen round.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; continuous interdigitizing with the secondary phloem or rays weakly regularly dilated, wedge-shaped. Well-defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters or as tangential discontinuous bands. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, well developed. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in ray cells, sclerenchyma, dilatation tissue, phellem, phelloderm and cortex, not encased in sclerotic elements and encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma and often randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) usually present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, or tangential diameter equal to radial diameter; cell walls U-shape thickened, with distinct cell lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals prisms, abundant. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark, with prisms abundant.

5.22 *Erythrococca berberidae* Prain (1676); Figure 22.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals styloids, abundant, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight, aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) **absent**.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; rays regularly dilated, wedge-shaped. Well defined dilatation meristem absent. Sclerenchyma absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **styloids**, abundant, located mainly in phloem parenchyma, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) occasionally present. Stratification present, lignified layers alternate with unlignified layers. Phellem cells mainly with tangential diameter greater than radial diameter, cell walls reversely U-shape thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells absent. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.23 *Erythrococca menyhartii* (Pax) Prain (1570, 1574); Figure 23.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells more or less isodiametric. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals styloids, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres, fibre-sclereids and sclereids**, in loose tangential groups or arranged in discontinuous tangential bands; fibres non-septate, walls thin to thick; fibre-sclereids axially rectangular; sclereids spheroidal, walls more or less even, lumen usually round, linear to constricted.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; irregular ('diffuse' type) or rays irregularly dilated, wedge-shaped. Well defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, poorly developed, comprising cellulosic fibres. Tanniniferous cells absent. Calcium oxalate crystals absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **styloids**, abundant, located mainly in ray cells, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark, usually with cells tangentially elongated.

5.24 *Euphorbia cooperi* N.E.Br. ex Berger (1580)

Sclerenchyma absent; dilatation tissue well developed; calcium oxalate crystals absent; axial crystalliferous strands absent; tanniniferous cells absent; secretory structures present (non-articulated laticifers); phellem with lignified cells absent; phelloderm sparse or poorly developed and cortex present.

5.25 *Euphorbia espinosa* Pax (1603); Figure 24

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1—3-seriate, course irregular; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth), **absent**.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; irregular ('diffuse' type) or rays regularly dilated, wedge-shaped. Well-defined dilatation meristem absent. Sclerenchyma absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **absent**.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures present, composed of non-articulated laticifers, randomly dispersed.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed.

CORTEX, Cortex present, forming a distinct zone in mature bark.

5.26 *Euphorbia ingens* E.Mey. ex Boiss. (1561).

Sclerenchyma absent, dilatation tissue well developed, calcium oxalate crystals absent, axial crystalliferous strands absent, tanniniferous cells absent, secretory structures present (non-articulated laticifers), mature periderm not observed and cortex present.

5.27 *Euphorbia tirucalli* L. (1562)

Sclerenchyma present (cellulosic fibres); dilatation tissue well developed, with sclerenchyma present (cellulosic fibres); calcium oxalate crystals present (micro-prisms); secretory structures present (non-articulated laticifers); phellem with lignified cells absent; phelloderm absent and cortex present.

5.28 *Flueggea virosa* (Roxb. ex Willd.) Voigt (1578, 1626, 1579); Figure 25.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells sparse. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal or isodiametric; 1-3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres and sclereids**; arranged in discontinuous tangential bands or forming staggered plates, tangential or elliptical in outline; fibres non-septate, walls thick to very thick; sclereids spheroidal, walls more or less even, lumen nearly always round, linear or constricted.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; irregular ('diffuse' type) or continuous interdigitizing with the secondary phloem. Well-defined dilatation meristem absent. Sclerenchyma absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **druses**, abundant, located mainly in ray cells and in dilatation tissue, not encased in sclerotic elements; **prisms**, abundant, associated with fibres in chambered crystalliferous strands, often encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma, rays and in dilatation tissue.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter or tangential diameter equal to radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.29 *Heywoodia lucens* Sim (1469, 1499); Figure 26.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals prisms and druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells hexagonal/isodiametric; 1—3-seriate, course more or less straight; portions of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids**; arranged in discontinuous tangential bands; sclereid shape spheroidal, hexagonal or rectangular, walls more or less even, lumen mainly following the shape of the encased prism.

DILATATION TISSUE. Dilatation tissue well developed, derived very often from rays only; type irregular ('diffuse' type) and rays regularly dilated and wedge-shaped. Well-defined dilatation meristem absent. Sclerenchyma present; secondarily formed sclereids hexagonal, irregularly dispersed as clusters and mainly associated with aggregates of primary sclerenchyma. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, well developed. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses**, abundant, located mainly in axial phloem parenchyma, ray cells, sclerenchyma, dilatation tissue and phelloderm; not encased in sclerotic elements or encased within sclereids. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous and sclerified, sclereids forming a sclerenchymatous ring. Parenchyma cells more or less isodiametric, with tangential diameter greater than radial diameter, or with tangential diameter equal to radial diameter. Sclereids more or less spheroidal, mainly confined to outer phloem, walls all evenly thickened. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.30 *Hyaenanche globosa* (Gaertn.) Lamb. (1810, 1815); Figure 27.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells sparse. Calcium oxalate crystals prisms, abundant, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1—3-seriate, course irregular; portion of rays traversing or adjacent to sclerenchyma occasionally lignified; aggregate rays absent. Ray cells thin-walled with abundant starch grains. Tile cells absent. Tanniniferous cells sparse. Calcium oxalate crystals prisms, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising nearly always **lignified fibres, rarely cellulosic fibres and fibre-sclereids**; forming scattered aggregates of loosely arranged elements and arranged in discontinuous tangential bands; fibres non-septate, walls thin to thick; fibre-sclereids usually rectangular.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays: continuous type forming a broad zone ('pseudocortex'). Well-defined dilatation meristem absent. Sclerenchyma present; secondarily formed sclereids spheroidal, irregularly scattered as idioblasts. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in axial phloem parenchyma; usually not encased in sclerotic elements, very occasionally encased within sclereids; abundant axially arranged chambered crystalliferous strands present, remaining parenchymatous, associated with sclerenchyma or randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phelloderm, but also sparsely dispersed in phloem parenchyma, phloem rays and dilatation tissue.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter equal to radial diameter. Lignified cells with tangential diameter equal to radial diameter or irregularly shaped; all walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm usually parenchymatous, very occasionally with slightly lignified walls; cells nearly always with tangential diameter greater than radial diameter. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.31 *Hymenocardia ulmoides* Oliv. (1595, 1596, 1597); Figure 28.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells more or less isodiametric. Tanniniferous cells abundant. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells usually radially elongated and thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibre-sclereids and sclereids**; forming staggered plates and arranged in discontinuous tangential bands, tangential or lenticular in outline; fibre-sclereids often radially elongated; sclereid shape spheroidal, vesiculose or rectangular, walls more or less even, lumen usually irregular, often undulating and very occasionally round.

DILATATION TISSUE. Dilatation tissue poorly developed or absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals sparse prisms, located mainly in sclerenchyma, encased within sclerotic elements. Axially arranged chambered crystalliferous strands present, sclerified, associated with fibre-sclereids or randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma, phloem rays, phellem and phelloderm.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter. Lignified cells with tangential diameter greater than radial diameter. Cell-walls U-shape thickened with clear cell lumen, walls distinctly pitted; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells abundant. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.32 *Lachnostylis bilocularis* R.A. Dyer (2213, 2214, 2215); Figure 29.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells sparse. Calcium oxalate crystals druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma often lignified; aggregate rays absent. Ray cells nearly always thin-walled, thick-walled cells usually tanniniferous. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres, fibre-sclereids and sclereids**; forming staggered plates and arranged in discontinuous tangential bands; mostly tangentially spindle-shaped in outline; fibres non-septate, walls thin to thick; sclereid shape spheroidal, walls more or less even, lumen round to linear.

DILATATION TISSUE. Dilatation tissue poorly developed or **absent.**

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in ray cells and sclerenchyma; druses not encased in sclerotic elements and prisms encased within sclereids. Axially arranged chambered crystalliferous strands present, sclerified, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells sparse, mainly in rays in the conducting phloem and sparse in the non-conducting phloem.

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter equal to radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.33 *Lachnostylis hirta* (L.f.) Muell.Arg. (2154, 2155, 2156, 2157); Figure 30.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells abundant. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres, fibre-sclereids, and sclereids**; arranged in discontinuous tangential bands; fibres non-septate, walls very thick; sclereid shape spheroidal or irregular, walls more or less even, lumen round to linear.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only; type irregular ('diffuse' type). Well-defined dilatation meristem absent. Sclerenchyma present, secondarily developed sclereids spheroidal or irregular, mainly associated with aggregates of primary sclerenchyma. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, poorly developed, with gelatinous fibres. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals mainly **prisms,** abundant, also **druses**, located mainly in sclerenchyma and dilatation tissue; druses not encased within sclerotic elements and prisms usually encased within sclereids. Axially arranged chambered crystalliferous strands present, usually sclerified and randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells abundant in all bark tissues.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Phellem cells walls staining red because of tanniniferous deposits. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells present. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells abundant. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark, with scattered sclereids (idioblasts), sparsely dispersed druses and abundant tanniniferous cells that are tangentially elongated.

5.34 *Macaranga capensis* (Baill.) Benth. ex Sim (1476, 1492, 1638, 1769, 1771, 1812); Figure 31.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells consisting of usually axially elongated. Tanniniferous cells abundant.

Calcium oxalate crystals druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, 2-4 rows of upright and/or square cells; 1—3-seriate, course irregular; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **fibres, fibre-sclereids and sclereids**; often scattered with solitary elements and very often forming irregular compact groups; fibres non-septate, walls often thin to thick; fibre-sclereids tangentially elongated; sclereid shape spheroidal or rectangular; walls more or less even, lumen round, hexagonal or slit-like.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; type irregular ('diffuse' type). Well-defined dilatation meristem absent. Sclerenchyma present; secondarily developed sclereids spheroidal, irregularly scattered as idioblasts and irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps) absent. Tanniniferous cells abundant. Calcium oxalate crystals druses, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in axial phloem parenchyma, sclerenchyma, and dilatation tissue, druses not encased within sclereids, and prisms encased within chambered axial strands associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, throughout bark, except in phellem.

SECRETORY STRUCTURES. Secretory structures present, composed of axial ducts with orange-red contents.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter; conspicuous radially elongated phellem absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous; cells with tangential diameter less than radial diameter or with tangential diameter equal to radial diameter. Tanniniferous cells abundant. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.35 *Margaritaria discoidea* (Baill.) Webster (4263, 1601, 1628); Figure 32.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, consisting of axially elongated cells. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal or isodiametric; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma usually lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising nearly always **fibres-sclereids**, and occasionally **sclereids**; arranged in discontinuous tangential bands or forming compact tangential groups; fibre-sclereids very thick-walled and radially elongated; sclereids spheroidal or axially elongated, walls more or less even, lumen nearly always round, occasionally slit-like.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only, continuous interdigitizing with the secondary phloem. Well-defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse, randomly dispersed or associated with sclereids.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses**, abundant, located mainly in sclerenchyma. Axially arranged chambered crystalliferous strands present, associated with sclerenchyma.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma and phloem rays.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification present, thin-walled cells alternate with thick-walled cells. Phellem cells mainly with tangential diameter greater than radial diameter, all cell-walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter, all cell-walls evenly thickened. Tanniniferous cells abundant. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.36 *Micrococca capensis* (Baill.) Prain (1770, 1796, 1805); Figure 33.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals styloids, sparse to abundant, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal or isodiametric, 1—3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals styloids, sparsely dispersed.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affeeby dilatation growth), **absent**.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays irregularly dilated, wedge-shaped. Well-defined dilatation meristem absent. Sclerenchyma absent. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] poorly developed, consisting of tangentially and distantly spaced small groups of cellulosic or lignified fibres. Tanniniferous cells absent. Calcium oxalate crystals styloids and prisms, sparsely and randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **styloids**, abundant, located mainly in axial phloem parenchyma, and prisms, sparse, located in dilatation tissue, phelloderm and cortex, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, all cell walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm very poorly developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; prisms present, sparse, randomly distributed.

5.37 *Phyllanthus cedrifolius* Verdoorn (1421); Figure 34.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth), present, comprising **fibre-sclereids and sclereids**; scattered in small randomly dispersed clusters, fibre-sclereids irregular in shape; sclereids spheroidal, walls more or less even, lumen round.

DILATATION TISSUE. Dilatation tissue poorly developed or absent. Well-defined meristem absent. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] present, comprising gelatinous and lignified fibres, forming tangential dense groups. Tanniniferous cells absent. Calcium oxalate crystals absent.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in ray cells, phelloderm and cortex, not encased in scleretic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent.**

SECRETORY STRUCTURES. Secretory structures **absent.**

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter or tangential diameter equal to radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter greater than radial diameter, cell walls all evenly thickened. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark, relatively broad (equal to secondary phloem in width), prisms present, randomly dispersed.

5.38 *Phyllanthus reticulatus* Poir (1584,1587); Figure 35.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms, abundant.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids**; forming irregular compact groups, sclereid shape spheroidal, walls more-or-less even, lumen round, linear or irregular.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; continuous forming a broad zone ('pseudocortex'). Well-defined dilatation meristem absent. Sclerenchyma present, secondarily derived sclereids spheroidal, irregularly dispersed as clusters, sometimes associated with sclereids of the phelloderm. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent; scattered lignified septate fibres, sclereids and gelatinous septate fibres present. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in ray cells and in dilatation tissue, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem rays, dilatation tissue, phelloderm and cortex.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, tangential diameter less than radial diameter, or tangential diameter equal to radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm sclerified; sclereids assembled in irregularly shaped groups, spheroidal, rectangular or irregular, with evenly thickened walls. Parenchyma cells mainly with tangential diameter greater than radial diameter, all cell-walls evenly thickened. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparsely dispersed in sclereids. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; tanniniferous cells present, abundant.

5.39 *Pseudolachnostylis maprounefolia* Pax (1543, 1565, 1566, 1593); Figure 36.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells more or less isodiametric. Tanniniferous cells sparse in conducting phloem, mainly associated with sclerenchyma. Calcium oxalate crystals prisms and druses, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal or isodiametric; 1—3-seriate, course more or less straight; portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells abundant. Calcium oxalate crystals predominantly druses; also prisms present, sparse, randomly dispersed.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids and fibre-sclereids**; arranged in discontinuous tangential bands or forming scattered regular groups with lens-shaped outline; fibre-sclereids often tangentially elongated, and rarely radially elongated; sclereids spheroidal, rectangular or irregular, walls more-or-less even, lumen round, linear, slit-like or irregular.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; continuous forming a broad zone ('pseudocortex'). Well-defined dilatation meristem absent. Sclerenchyma present; secondarily derived sclereids large, shape spheroidal, tangentially elongated, irregular, or rectangular, irregularly dispersed as clusters. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps) absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms and druses,** abundant, located mainly in axial phloem parenchyma, ray cells, sclerenchyma and phelloderm; crystals not encased in sclerotic elements in phloem parenchyma and phloem rays, otherwise encased within sclereids. Axially arranged sclerified chambered crystalliferous strands present, randomly dispersed.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in rays, non-conducting phloem parenchyma, dilatation tissue and phelloderm.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) occasionally present. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, lignified cells with tangential diameter greater than radial diameter or tangential diameter equal to radial diameter, cell-wall thickening U-shaped with distinct lumen; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm occasionally well developed. Stratification absent. Phelloderm parenchymatous and partly sclerified, cells mainly with tangential diameter greater than radial diameter, sclereid shape spheroidal, rectangular, cell-walls with U-shaped uneven thickening. Tanniniferous cells abundant. Calcium oxalate crystals prisms, abundant. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex present, forming a distinct zone in mature bark; parenchyma cells with walls partly lignified.

5.40 *Sapium ellipticum* (Hochst.) Pax (1511, 1656, 1787); Figure 37.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal/isodiametric; 1—3-seriate, course more or less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals absent.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **sclereids, lignified fibres and cellulosic fibres**; forming scattered aggregates of loosely arranged elements; fibre groups more or less circular in outline; fibres non-septate, walls thin to thick; sclereids forming regular compact groups, shaped spheroidal, rectangular or square, walls more-or-less even, lumen round, slit-like, elongated or irregular.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; irregular ('diffuse' type). Well-defined dilatation meristem absent. Sclerenchyma absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant, forming axial strands associated with sclerenchyma, randomly distributed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in crystalliferous cells, wreathing the sclerenchyma and in dilatation tissue, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.41 *Sapium integerrimum* (Hochst.) J.Leonard (1682,1691); Figure 38.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically hexagonal or isodiametric; 1—3-seriate, course more-or-less straight, portion of rays traversing or adjacent to sclerenchyma lignified; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **cellulosic fibres, lignified fibres and sclereids**; cellulosic fibres scattered with solitary elements, lignified fibres forming scattered aggregates of loosely arranged elements and sclereids forming regular compact aggregates more or less circular in outline. Fibres non-septate, walls thin to thick; sclereid shape spheroidal, walls more or less even, lumen round, linear to slit-like.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma and rays; type continuous forming a broad zone ('pseudocortex') or interdigitizing with the secondary phloem. Well-defined dilatation meristem absent. Sclerenchyma absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, sparse, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, sparse, located mainly in crystalliferous cells, weakly wreathing the sclerenchyma and in dilatation tissue, very often not encased in sclerotic elements and occasionally encased within sclereids. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or very poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.42 *Spirostachys africana* Sond. (1577, 1612); Figure 39.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells sparse. Calcium oxalate crystals prisms, abundant, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically procumbent; 1—3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells sparse. Calcium oxalate crystals prisms, sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) present, comprising **exclusively cellulosic fibres**; scattered with solitary elements or forming scattered aggregates of loosely arranged elements; fibres non-septate, walls thin to thick.

DILATATION TISSUE. Dilatation tissue well developed, derived from phloem parenchyma only; continuous forming a broad zone ('pseudocortex'). Well-defined dilatation meristem absent. Sclerenchyma absent. Tanniniferous cells abundant. Calcium oxalate crystals prisms, abundant, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **prisms**, abundant, located mainly in axial phloem parenchyma, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells abundant, mainly in phloem parenchyma, dilatation tissue and phelloderm.

SECRETORY STRUCTURES. Secretory structures present, composed of non-articulated laticifers, randomly dispersed.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells usually with tangential diameter greater than radial diameter, very occasionally with tangential diameter less than radial diameter, and very rarely with tangential diameter equal to radial diameter; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells more or less isodiametric, mainly with tangential diameter greater than radial diameter. Tanniniferous cells abundant. Calcium oxalate crystals prisms, sparse. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.43 *Suregada africana* (Sond.) Kuntze (1654); Figure 40.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements, cells axially elongated. Tanniniferous cells absent. Calcium oxalate crystals absent.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals druses, abundant, arranged in radial rows. Rays regularly dilated.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth) **absent**.

DILATATION TISSUE. Dilatation tissue well developed, derived from rays only, rays regularly dilated, wedge-shaped. Well-defined dilatation meristem absent. Sclerenchyma present, abundant; secondarily derived sclereids spheroidal, irregularly dispersed as clusters or forming more-or-less continuous broad bands. Sclerenchyma ring (persistent primary phloem fibres) [phloem caps] absent. Tanniniferous cells absent. Calcium oxalate crystals prisms, abundant, randomly dispersed.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals **druses**, abundant, not encased in sclerotic elements, located mainly in ray cells, **prisms** located in sclerenchyma, in dilatation tissue, and encased within sclereids. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent**.

SECRETORY STRUCTURES. Secretory structures **absent**.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) present. Stratification absent. Phellem cells mainly with tangential diameter equal to radial diameter, all cell-walls evenly thickened; conspicuous radially enlarged phellem cells absent. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm absent or poorly developed. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex **absent** in mature bark.

5.44 *Synadenium cupulare* (Boiss.) L.C.Wheeler (1609); Figure 41.

AXIAL PHLOEM PARENCHYMA. Axial phloem parenchyma diffuse between sieve tube elements and in weak tangential lines, cells more or less isodiametric cells. Tanniniferous cells absent. Calcium oxalate crystals micro-prisms, sparse, randomly dispersed.

PHLOEM RAYS. Phloem rays heterocellular, cells typically square and/or upright; 1—3-seriate, course more or less straight or undulated; aggregate rays absent. Ray cells thin-walled. Tile cells absent. Tanniniferous cells absent. Calcium oxalate crystals sparse.

SCLERENCHYMA. Sclerenchyma (in secondary phloem not affected by dilatation growth), **absent**.

DILATATION TISSUE. Dilatation tissue **poorly developed or absent**.

CALCIUM OXALATE CRYSTALS. Calcium oxalate crystals prisms, abundant, located mainly in dilatation tissue, not encased in sclerotic elements. Axially arranged chambered crystalliferous strands absent.

TANNINIFEROUS CELLS. Tanniniferous cells **absent.**

SECRETORY STRUCTURES. Secretory structures present, composed of non-articulated laticifers, randomly scattered: axially elongated in secondary phloem and tangentially elongated in cortex, rarely axially elongated, occasionally branched.

MATURE PERIDERM. Periderm arrangement ramified (net-like). Phellem compact; lignified cells (phellem/phelloid) absent. Stratification absent. Phellem cells mainly with tangential diameter greater than radial diameter, all walls evenly thickened. Idioblasts absent. Calcium oxalate crystals absent. Phelloderm well developed. Stratification absent. Phelloderm parenchymatous, cells mainly with tangential diameter equal to radial diameter. Tanniniferous cells absent. Calcium oxalate crystals absent. Chloroplasts not observed. Lenticels not observed.

CORTEX. Cortex well developed, broader than secondary phloem, orientation of laticifers mark the secondary phloem from the cortex, crystals micro-prisms, abundant, scattered in cortex. No pericylic fibres demarcate the boundary between the phloem and cortex.

5.45 *Uapaca kirkiana* Muell. Arg. (1640, 1641, 1643)

5.46 *Uapaca sansibarica* Pax (1638, 1639)

Sclerenchyma present (sclereids and fibre-sclereids); dilatation tissue sparse or poorly developed; calcium oxalate crystals absent; axial chamberd crystalliferous strands not observed; phellem with lignified cells present, phelloderm present and cortex absent.

CHAPTER 6

TAXONOMIC SIGNIFICANCE OF BARK ANATOMICAL CHARACTERS

6.1 INTRODUCTION

Significant work on the anatomy of certain members of the Euphorbiaceae has been done by a number of authors (e.g. Pax 1884; Solereder 1908; Metcalfe & Chalk 1950; Roth 1981; Mennega 1986; Rudall 1986; Mahlberg *et al.* 1986).

Roth (1981) did far-reaching meritorious work on a broad spectrum of structural patterns of tropical barks of 48 families. The bark samples were collected in Venezuela. One of the 48 families is the Euphorbiaceae from which she studied 13 genera. Only four of these (*Croton, Drypetes, Margaritaria* and *Sapium*) are represented in southern Africa. In the present study, the bark anatomical characters of these four genera plus 23 others that contain 44 species and are present in southern Africa, are described. The genera are arranged according to Webster's (1975, 1987) system of classification.

The family Euphorbiaceae is heterogeneous, highly diversified ecologically as well as morphologically and biochemically (Cronquist 1981; Webster 1987; Meeuse 1990). In this study an attempt is made to assess the taxonomic importance of the various bark anatomical features in woody southern African Euphorbiaceae. The anatomical features investigated include various characters of bark tissues/cells of the following: axial phloem parenchyma, phloem rays, sclerenchyma, dilatation tissue, calcium oxalate crystals, tanniniferous cells, secretory structures, mature periderm and cortex.

Although sieve elements are a component of the conducting bark, they have been omitted in the present study for reasons stated in Chapter 2, 2.4.1 Sieve elements, of this study. Future technological advancement will hopefully allow for their meaningful comparative study.

In this chapter the taxonomic significance of the various bark tissues will be discussed separately. Attention will be given to both lower and higher taxonomic levels. Particular emphasis is placed on the taxonomic significance at the species level (6.12). Statements made here refer to the investigated taxa, unless indicated otherwise. Because of the brief descriptions given for succulent *Euphorbia cooperi, E. ingens* and *E. tirucalli* and woody *Uapaca* sp. in Chapter 5, these taxa have not been considered for certain characters in this chapter.

Character states and taxa are listed in a way that may be used as a type of synoptic key — for this purpose certain character states have been printed in bold. Such a synoptic key may be used with data from optical microscopy only. This would not, in most cases, lead the user to the single correct species, but would at least allow him to eliminate a large number of other possibilities. An analytical key would necessitate the use of all the characters (Coetzee 1975). This chapter is concluded with a dichotomous key, which utilizes some of the more reliable bark anatomical characters. See also Table 6 in Part 2, for a comparative exposition of selected bark anatomical characters in the different taxa.

6.2 AXIAL PHLOEM PARENCHYMA

The diffuse distribution of axial phloem parenchyma between sieve elements is a constant feature in all subfamilies, except in some investigated Acalyphoideae. It is nevertheless a strong trend within this subfamily because it is only in *Acalypha glabrata* var. *pilosior* that the axial phloem parenchyma forms weak tangential rows.

The shape of axial phloem parenchyma cells varies from the axially elongated to more or less isodiametric. The trend in all subfamilies is towards the axially elongated state.

Tanniniferous cells are present in the axial phloem parenchyma of all the subfamilies. However, members of the subfamily Acalyphoideae display a strong trend towards absence of tanniniferous cells, because it is only in one subtribe, the Macaranginae, that tanniniferous cells are present in axial phloem parenchyma.

The following taxa lack tanniniferous cells in axial phloem parenchyma:

Tribes:

- Drypeteae (subfamily Phyllanthoideae)
- Crotoneae (subfamily Crotonoideae)
- Euphorbieae (subfamily Euphorbioideae)

Subtribes: Cluytieae (subfamily Acalyphoideae)

- Claoxylinae (subfamily Acalyphoideae)
- Acalyphinae (subfamily Acalyphoideae)
- Gelonieae (subfamily Crotonoideae)

Genera and species:

Subfamily Phyllanthoideae

- Tribe: Wielandieae

    Heywoodia lucens

- Tribe: Bridelieae

    Cleistanthus schlecteri

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Margaritaria discodea

        Phyllanthus cedrifolius

Subfamily Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Sapium ellipticum

        S. integerrimum

Generally, the presence or absence and type of calcium oxalate crystals in axial phloem parenchyma are not constant in the subfamilies, tribes, subtribes and genera. However, in tribe Drypetae all the *Drypetes* species lack crystals. In subtribe Acalyphinae all *Acalypha* species contain crystals, but the types of crystals are different. *Acalypha glabrata* var. *glabrata* bears styloids, while both *Acalypha glabrata* var. *pilosior* and *A. sonderiana* contain druses. On the whole, where crystals occur they are randomly dispersed within the axial phloem parenchyma.

6.3 PHLOEM RAYS

Metcalfe & Chalk (1950) found xylem rays in the wood of the Euphorbiaceae to be heterogeneous (heterocellular). In all the taxa of the Euphorbiaceae that Kromhout (1975) described the observed the xylem rays to be heterocellular. Since phloem rays are continuous through the cambium with those of the xylem, the overall development and structure of the vascular rays in the phloem tissue (phloem rays) parallel those of the xylem (Esau 1976). In the present study, although it was not decisively clear whether phloem rays were heterocellular or homocellular, because only transverse and radial sections were made, it is most probable that phloem rays in the Euphorbiaceae are predominantly heterocellular.

The shape of phloem ray cells ranges from square and/or upright to hexagonal or isodiametric. The width of phloem rays is 1—3-seriate, but in *Androstachys johnsonii* it is exclusively uniseriate. In *Antidesma venosum* and *Cleistanthus schlecteri* the phloem rays may be up to 5-seriate. The course of the rays is more or less straight, but irregular in *Hyaenanche globosa* and *Macaranga capensis*.

In most taxa the portion of phloem ray traversing or adjacent to sclerenchyma is lignified. In the following species it remains parenchymatous:

Subfamily Phyllanthoideae

- Tribe: Bridelieae

    Bridelia cathartica

    B. micrantha

    Cleistanthus schlecteri

- Tribe: Porantheraeae

    Subtribe: Poranthereae

        Andrachne ovalis

- Tribe: Antidesmeae

    Antidesma venosum

Subfamily Acalyphoideae

- Tribe: Clutieae

    Subtribe: Cluytieae

        Clutia pulchella

Subfamily Crotonoideae

- Tribe: Crotoneae

    Croton sylvaticus

Aggregate phloem rays and tile cells are absent. Ray cell walls are thin.

Taxa that lack or possess tanniniferous cells in their axial phloem parenchyma cells, also lack or possess tanniniferous cells in their phloem rays. The occurrence or non-occurrence of tanniniferous cells in these two tissues is mutually inclusive.

Occurrence of calcium oxalate crystals in phloem rays is independent of their presence in the axial phloem parenchyma. **The folowing contain crystals in the phloem rays, but not in the axial phloem parenchyma:**

Subfamily Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis hirta

- Tribe: Drypeteae

    Drypetes arguta

    D. gerrardii

    D. natalensis

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Flueggea virosa

        Margaritaria discodea

Subfamily Crotonoideae

- Tribe: Gelonieae

    Subtribe: Gelonieae

        Suregada africana

- Tribe: Crotoneae

    Croton gratissimus

    C. pseudopulchellus

Subfamilies Oldfieldioideae, Acalyphoideae and Euphorbioideae do not exhibit this trend. All three species of *Drypes*, subtribe Drypeteae, show a strong tendency towards the above-mentioned trend, as they all contain prisms in their phloem rays.

The presence and abundance of crystals is not influenced by the occurrence and the abundance of tanniniferous cells present in the phloem rays. The following bear evidence to this, since **both crystals and tanniniferous cells abound in their phloem rays:**

Subfamily Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis bilocularis

    L. hirta

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia

    Subtribe: Flueggeinae

        Phyllanthus reticulatus

Subfamily Crotonoideae

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea

In phloem rays of the following taxa, there are crystals, but tanniniferous cells are absent:

Tribes: Drypeteae (subfamily Phyllanthoideae)

Gelonieae (subfamily Crotonoideae)

Crotoneae (subfamily Crotonoideae)

Subtribe: Acalyphinae (subfamily Acalyphoideae)

Genera and species:

Subfamily Phyllanthoideae

- Tribe: Wielandieae

  Heywoodia lucens

- Tribe: Bridelieae

  Cleistanthus schlecteri

- Tribe: Phyllantheae

  Subtribe: Flueggeinae

  Margaritaria discodea

  Phyllanthus cedrifolius

Subfamily Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Claoxylinae

  Erythrococca menyhartii

  Subtribe: Alcalyphinae

  Micrococca capensis

Subfamily Euphorbioideae

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Sapium integerrimum

All subfamilies, except subfamily Crotonoideae, contain some members that lack crystals in phloem rays. **Taxa in which crystals are absent in phloem rays include the following:**

Subfamily Phyllanthoideae

- Tribe: Bridelieae

    Bridelia mollis

- Tribe: Porantthereae

    Subtribe: Poranthereae

        Andrachne ovalis

- Tribe: Hymenocardieae

    Subtribe: Hymenocardieae

        Hymenocardia ulmoides

Subfamily Oldfieldioideae

- Tribe: Petalostigmateae

    Subtribe: Petalostigmatinae

        Androstachys johnsonii

Subfamily Acalyphoideae

- Tribe: Clutieae

    Subtribe: Cluytieae

        Clutia pulchella

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca berberidae

Subfamily Euphorbioideae

- Tribe: Hippomanae

  Subtribe: Hippomaninae

  Sapium ellipticum

6.4 SCLERENCHYMA

The sclerenchyma discussed here is part of secondary phloem that is not affected yet by dilatation growth. **Sclerenchyma is present in all subfamilies, except in some members of subfamilies Acalyphoideae, Crotonoideae and Euphorbioideae. These members include**:

Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Acalyphinae

  Acalypha glabrata var. *pilosior*

- Tribe: Clutieae

  Subtribe: Cluytieae

  Clutia pulchella

- Tribe: Acalypheae

  Subtribe: Claoxylinae

  Erythrococca berberidae

  Micrococca capensis

Crotonoideae

- Tribe: Gelonieae

    Subtribe: Gelonieae

        Suregada africana

Euphorbioideae

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Euphorbia cooperi

        Euphorbia espinosa

        Euphorbia ingens

        Synadenium cupulare

The cells comprising the sclerenchyma where present, can be grouped into one of six types, namely fibres; sclereids; fibres and sclereids; fibres, sclereids and fibre-sclereids; fibres and fibre-sclereids and sclereids and fibre-sclereids.

Subfamily Phyllanthoideae taxa exhibit all six types of sclerenchyma:

Fibres only

- Tribe: Bridelieae

    Bridelia cathartica

    B. mollis

Sclereids only

- Tribe: Wielandieae

  Heywoodia lucens

- Tribe: Phyllantheae

  Subtribe: Flueggeinae

    Phyllanthus reticulatus

Fibres and sclereids

- Tribe: Bridelieae

  Bridelia micrantha

- Tribe: Phyllantheae

  Subtribe: Securineginae

    Flueggea virosa

- Tribe: Drypeteae

  Drypetes natalensis

Fibres, sclereids and fibre-sclereids

- Tribe: Wielandieae

  Lachnostylis bilocularis

  L. hirta

- Tribe: Antidesmeae

  Antidesma venosum

- Tribe: Drypeteae

  Drypetes gerrardi

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Margaritaria discodea

Fibres and fibre-sclereids

- Tribe: Bridelieae

    Cleistanthus schlecteri

- Tribe: Drypeteae

    Drypetes arguta

Sclereids and fibre-sclereids

- Tribe: Poranthereae

    Subtribe: Poranthereae

        Andrachne ovalis

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia

- Tribe: Phyllantheae

    Subtribe: Flueggeniae

        Phyllanthus cedrifolius

- Tribe: Hymenocardieae

    Subtribe: Hymenocardieae

        Hymenocardia ulmoides

Taxa of subfamily Olfieldioideae contain two types of sclerenchyma:

Fibres and sclereids

- Tribe: Petalostigmateae

  Subtribe: Petalostigmatinae

  Androstachys johnsonii

Fibres and fibre-sclereids

- Tribe: Hyaenancheae

  Subtribe: Hyaenanchinae

  Hyaenanche globosa

There are three types of sclerenchyma in subfamily Acalyphoideae:

Sclereids only

- Tribe: Acalypheae

  Subtribe: Acalyphinae

  Acalypha glabrata var. *glabrata*

Fibres, sclereids and fibre-sclereids

- Tribe: Acalypheae

  Subtribe: Macaranginae

  Macaranga capensis

  Subtribe: Claoxylinae

  Erythrococca menyhartii

Sclereids and fibre-sclereids

- Tribe: Acalypheae

    Subtribe: Acalyphinae

        Acalypha sonderiana

The subfamily Crotonoideae exhibits three types of sclerenchyma:

Fibres only

- Tribe: Crotoneae

    Croton megalobotrys

Sclereids only

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea

Fibres and sclereids

- Tribe: Crotoneae

    Croton gratissimus

    C. menyhartii

    C. pseudopulchellus

    C. sylvaticus

Subfamily Euphorbioideae exhibits two types of sclerenchyma composition:

Fibres only (exclusively cellulosic fibres)

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Spirostachys africana

Fibres and sclereids

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Sapium ellipticum

  S. integerrimum

In this study, the sclereid types and classification as observed in transverse sections follow those of Rao & Bhupal (1973). These workers recognize two basic cell shapes in sclereids, namely monomorphic and polymorphic. Monomorphic sclereids have a uniform simple base shape with even or uneven outlines. Polymorphic sclereids have extremely complex base forms with uneven outlines and branching that lead to symmetrical or asymmetrical sclereid shapes.

The representation of all subfamilies studied exhibit the monomorphic type of sclereids. The monomorphic body shapes include the spheroidal sclereids; vesiculose sclereids; vermiform sclereids; palosclereids; osteosclereids and fusiform sclereids. The spheroidal shape is encountered in all subfamilies where sclereids are present. This shape is spheroidal, globoid, orbiculate, pyriform or turbinate (Rao & Bhupal 1973). In the spheroidal sclereid category, the sclereids exhibit thin walls with wide lumina or thick walls, often pitted with narrow lumina.

6.5 DILATATION TISSUE

This tissue develops from phloem rays, axial phloem parenchyma or from both. In some taxa secondarily formed sclereids are encountered. In other taxa persistent primary phloem fibres (phloem caps) are present. Tanniniferous cells and calcium oxalate crystals may be present or absent in this tissue. Dilatation tissue is either well developed, absent or poorly developed.

In members of the following subfamilies dilatation tissue is absent or poorly developed:

Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis bilocularis

- Tribe: Bridelieae

    Bridelia cathartica

    B. mollis

    Cleistanthus schlecteri

- Tribe: Antidesmeae

    Antidesma venosum

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Phyllanthus cedrifolius

- Tribe: Hymenocardieae

    Subtribe: Hymenocardieae

Hymenocardia ulmoides

Oldfieldioideae

- Tribe: Petalostigmateae

    Subtribe: Petalostigmatinae

        Androstachys johnsonii

Euphorbiordeae

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Synadenium cupulare

In subfamilies Acalyphoideae, Crotonoideae and Euphorbioideae (at least in woody members), a well developed dilatation tissue is present in all the genera studied.

Although Roth (1981) states that patterns of dilatation growth may be specific, and therefore be used for identification, in this study, it was observed that the origins and types of the dilatation tissue are taxonomically insignificant. Moreover, it is not always clear whether the dilatation tissue is developed from phloem rays, phloem parenchyma or from both. Dilatation tissue meristem was not observed in all the taxa studied.

Secondarily derived sclereids are almost always present in the dilatation tissue. However, **in the well developed dilatation tissue of the following subfamilies these sclereids were not observed:**

Phyllanthoideae

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Flueggea virosa

Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca berberidae

        Micrococa capensis

- Tribe: Acalypheae

    Subtribe: Acalyphinae

        Acalypha glabrata var. *glabrata*

        A. glabrata var. *pilosior*

Crotonoideae

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea

Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Sapium ellipticum

        S. integerrimum

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Euphorbia espinosa

There is a correlation with regard to the presence or absence of tanniniferous cells in the dilatation tissue. Where there are abundant tanniniferous cells in phloem parenchyma and phloem rays, tanniniferous cells are also abundant in the dilatation tissue. The following taxa display this pattern:

Subfamily Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis hirta

- Tribe: Bridelieae

    Bridelia micrantha

    B. mollis

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Flueggea virosa

    Subtribe: Flueggeinae

        Phyllanthus reticulatus

Subfamily Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Macaranginae

        Macaranga capensis

Subfamily Crotonoideae

- Tribe: Aleuritideae

  Subtribe: Grosserinae

  Cavacoa aurea

Where tanniniferous cells are absent both in axial phloem parenchyma and phloem rays, they are also absent in the dilatation tissue. The following exhibit this trend:

Subfamily Phyllanthoideae

- Tribe: Wielandieae

  Heywoodia lucens

- Tribe: Drypeteae

  Drypetes arguta

  D. gerrardi

  D. natalensis

- Tribe: Phyllantheae

  Subtribe: Flueggeinae

  Margaritaria discodea

Subfamily Acalyphoideae

- Tribe: Clutieae

  Clutia pulchella

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca berberidae

        E. menyhartii

        Micrococca capensis

- Tribe: Acalypheae

    Subtribe: Acalyphinae

        Acalypha glabrata var. *glabrata*

        A. glabrata var. *pilosior*

        A. sonderiana

Subfamily Crotonoideae

- Tribe: Geloniea

    Subtribe: Gelonieae

        Suregada africana

- Tribe: Crotoneae

    Croton megalobotrys

    C. sylvaticus

Subfamily Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Sapium ellipticum

        S. integerrimum

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Euphorbia espinosa

Some of the taxa studied deviate from the two above-mentioned trends, as evidenced by the following:

Dilatation tissue with sparse tanniniferous cells but tanniniferous cells absent in both phloem parenchyma and phloem rays:

Subfamily Crotonoideae

- Tribe: Crotoneae

    Croton gratissimus

    C. menyhartii

    C. pseudopulchellus

Dilatation tissue with abundant tanniniferous cells, but tanniniferous cells are sparse in both phloem parenchyma and phloem rays:

Subfamily Oldfieldioideae

- Tribe: Hyaenancheae

    Subtribe: Hyaenanchinae

        Hyaenanche globosa

Subfamily Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Spirostachys africana

Calcium oxalate crystals are present in the dilatation tissue of all subfamilies, but absent in a few representatives of some subfamilies. Crystals found are prisms, druses and styloids.

Crystals are absent in the dilatation tissue of the following:

Subfamily Phyllanthoideae

- Tribe: Poranthereae

    Subtribe: Poranthereae

        Andrachne ovalis

Subfamily Acalyphoideae

- Tribe: Clutieae

    Subtribe: Cluytieae

        Clutia pulchella

Subfamily Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca berberidae

        E. menyhartii

Subfamily Euphorbioideae

- Tribe: Euphorbieae

  Subtribe: Euphorbiinae

  Euphorbia espinosa

The type(s) of crystals present in the dilatation tissue are usually also present in either the phloem parenchyma, phloem rays or in both. This phenomenon may be indicative of the derivation of the dilatation tissue from either the phloem parenchyma, phloem ray or from both.

The following arrangements indicate this trend:

Prisms present in both dilatation tissue and phloem parenchyma:

Subfamily Euphorbioideae

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Sapium ellipticum

Prisms present in both dilatation tissue and phloem rays:

Subfamily Phyllanthoideae

- Tribe Drypeteae

  Drypetes arguta

  D. natalensis

Subfamily Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Sapium integerrimum

Druses present in both dilatation tissue and phloem rays:

Subfamily Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis hirta

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Flueggea virosa

Subfamily Crotonoideae

- Tribe: Crotoneae

    Croton gratissimus

Dilatation tissue, phloem parenchyma and phloem rays of the following contain the same type of crystal:

Prisms

Subfamily Phyllanthoideae

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Phyllanthus reticulatus

Subfamily Oldfieldioideae

- Tribe: Hyaenancheae

    Subtribe: Hyaenanchinae

        Hyaenanche globosa

Subfamily Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Spirostachus africana

Druses

Subfamily Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Macaranginae

        Macaranga capensis

Subfamily Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Acalyphinae

        Acalypha sonderiana

Subfamily Crotonoideae

- Tribe: Crotoneae

    Croton sylvaticus

Styloids

Subfamily Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Micrococca capensis

There are also combinations of types of crystals in the dilatation tissues:

Subfamily Crotonoideae

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea — dilatation tissue (prisms and druses), phloem parenchyma (prisms) and phloem rays (druses).

Subfamily Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Acalyphinae

        Acalypha glabrata var. *glabrata* — dilatation tissue (prisms and styloids), phloem parenchyma (styloids) and phloem rays (prisms and styloids).

Deviations from the above-mentioned states are encountered, as indicated by the following:

Subfamily Phyllanthoideae

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Margaritaria discodea — dilatation tissue (prisms) and phloem rays (druses)

Subfamily Phyllanthoideae

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia — dilatation tissue (prisms), phloem parenchyma (prisms and druses) and phloem rays (prisms and druses)

Subfamily Crotonoideae

- Tribe: Gelonieae

    Subtribe: Gelonieae

        Suregada africana — dilatation tissue (prisms) and phloem rays (druses)

- Tribe Crotoneae

    Croton pseudopulchellus — dilatation tissue (prisms) and phloem rays (druses)

6.6 CALCIUM OXALATE CRYSTALS

Where calcium oxalate crystals are present in the barks studied, they are prisms, druses or styloids. Prisms are abundant in occurrence. Next in line are druses, and styloids are the least in occurrence. Crystals are located in any of the following parts of the bark: axial phloem parenchyma, phloem rays, sclerenchyma, dilatation tissue, axial crystalliferous strands, phellem, phelloderm and cortex.

It is noteworthy that prisms are sometimes encased either in sclerotic elements and parenchyma cells, whereas druses and styloids only occur in parenchyma cells.

Crystals are present in all subfamilies, but are absent in some members of certain subfamilies. **Crystals are absent in the entire barks of the following:**

Subfamily Phyllanthoideae

- Tribe: Porantherae

    Subtribe: Porantherae

        Andrachne ovalis

Subfamily Acalyphoideae

- Tribe: Clutieae

  Subtribe: Cluytieae

  Clutia pulchella

Subfamily Euphorbioideae

- Tribe: Euphorbieae

  Subtribe: Euphorbiinae

  Euphorbia cooperi

  E. espinosa

  E. ingens

Prisms and druses together are present in all subfamilies, except in subfamilies Oldfieldioideae and Euphorbioideae. Dual presence of prisms and druses is common to all subfamilies, except to subfamily Euphorbioideae. Styloids are only present in subfamily Acalyphoideae, tribe Acalypheae, subtribes Claoxylinae and Acalyphinae. A combination of prisms, druses and styloids was not encountered in any subfamily. Druses and styloids were not encountered together in the same bark. **A combination of prisms and styloids is found only in:**

Subfamily Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Claoxylinae

  Erythrococca menyhartii

  Micrococca capensis

Subtribe: Acalyphinae

Acalypha glabrata var. *glabrata*

Representatives of the following subfamilies contain only prisms:

Phyllanthoideae

- Tribe: Bridelieae

    Bridelia mollis

- Tribe: Drypeteae

    Drypetes arguta

    D. natalensis

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

    Phyllanthus cedrifolius

    P. reticulatus

- Tribe: Hymenocardieae

    Subtribe: Hymenocardieae

    Hymenocardia ulmoides

Oldfieldioideae

- Tribe: Hyaenancheae

    Subtribe: Hyaenanchinae

    Hyaenanche globosa

- Tribe: Petalostigmateae

    Subtribe: Petalostigmatinae

    Androstachys johnsonii

Euphorbioideae

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Sapium ellipticum

  S. integerrimum

  Spirostachys africana

- Tribe: Euphorbieae

  Subtribe: Euphorbiinae

  Euphorbia tirucalli

  Synadenium cupulare

Druses only, are present in the following subfamilies:

Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Acalyphinae

  Acalypha glabrata var. *pilosior*

Crotonoideae

- Tribe: Crotoneae

  Croton megalobotrys

Styloids only, are present in:

Subfamily Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Claoxylinae

  Erythrococca berberidae

Roth (1981) writes that the appearance of crystals in the bark is common, and as a result she did not usually take them into account. The presence or absence, type and location of crystals may be useful in taxonomic classification (Esau 1977; Fahn 1982).

In this study it was observed that representatives of subfamily Phyllantoideae contain prisms and druses, prisms only or lack crystals. Subfamily Oldfieldioideae exhibit prisms only. Styloids were only encountered in subfamily Acalyphoideae. Members display prisms and druses, prisms and styloids, druses only, styloids only, or lack crystals. Representatives of subfamily Crotonoideae contain predominantly prisms and druses. Prisms or lack of crystals typify the subfamily Euphorbioideae.

6.7 AXIAL CHAMBERED CRYSTALLIFEROUS STRANDS

Axial chambered crystalliferous strands are present in all subfamilies, except in subfamily Euphorbioideae. These axial crystalliferous strands may either be associated with sclerenchyma or may occur randomly dispersed and unassociated with sclerenchyma. They may be sclerified or may remain parenchymatous.

Axial chambered crystalliferous strands are present in representatives of the following subfamilies:

Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis bilocularis

    L. hirta

- Tribe: Bridelieae

    Bridelia cathartica

    B. micrantha

    B. mollis

- Tribe: Drypeteae

    Drypetes arguta

    D. gerrardii

    D. natalensis

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia

    Subtribe: Fluegeinae

        Flueggea virosa

        Margaritaria discodea

- Tribe: Hymenocardieae

    Subtribe: Hymenocardieae

        Hymenocardia ulmoides

Oldfieldioideae

- Tribe: Hyaenancheae

  Subtribe: Hyaenanchinae

  Hyaenanche globosa

- Tribe: Petalostigmateae

  Subtribe: Petalostigmatinae

  Androstachys johnsonii

Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Macaranginae

  Macaranga capensis

  Subtribe: Acalyphinae

  Acalypha glabrata var. *pilosior*

  A. sonderiana

Crotonoideae

- Tribe: Aleuritideae

  Subtribe: Grosserinae

  Cavacoa aurea

- Tribe: Crotoneae

  Croton gratissimus

  C. menyhartii

  C. pseudopulchellus

The following representatives exhibit axial chambered crystalliferous strands that are randomly dispersed and are not associated with sclerenchyma:

Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis hirta

- Tribe: Drypeteae

    Drypetes arguta

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia

Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Acalyphinae

        Acalypha glabrata var. *pilosior*

Crotonoideae

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea

In all other representatives of the subfamilies where axial chambered crystalliferous strands are present they are associated with sclerenchyma.

According to Roth (1981), a definite relationship between the occurrence of septate crystal strands (axial chambered crystalliferous strands) and presence of true fibres may be observed in the Euphorbiaceae. She further states that septate crystal strands may occur when only fibres are formed or when a mixture of fibres and sclereid is present.

In this study the types of axial chambered crystalliferous strands encountered are associated with sclerenchyma (fibres, fibre-sclereids, sclereids) and others are randomly dispersed and are not associated with sclerenchyma.

Axial chambered crystalliferous strands in *Margaritaria discodea* are associated with fibre-sclereids and sclereids. In *Hymenocardia ulmoides* they are associated with fibre-sclereids. These observations would suggest that axial chamberd crystalliferous strands and these lignified sclerotic elements are most probably derived from the same fusiform cambial initials as the fibres. The relationship between presence of real fibres and axial chambered crystalliferous strand formation was also observed to hold in all families studied by Roth (1981).

6.8 TANNINIFEROUS CELLS

Tannins are a heterogeneous group of phenol derivatives that are widely distributed in the plant body (Esau 1977). Cells containing these phenol derivatives are referred to as tanniniferous cells. They may be present as the predominant cell type in a given tissue or as isolated cells in a tissue. Phenolic compounds are useful as supplementary indicators of taxonomic relationships (Bate-Smith 1962).

Tannins are among the most common contents in bark (Roth 1981). In this study tanniniferous cells were encountered in the axial phloem parenchyma, phloem rays, dilatation tissue and phelloderm.

Although tanniniferous cells are present in the barks of all subfamilies studied, **some representatives of tribes and subtribes lack tanniniferous cells. Such representatives are in the following subfamilies:**

Phyllanthoideae

- Tribe: Wielandieae

    Heywoodia lucens

- Tribe: Bridelieae

    Cleistanthus schlecteri

- Tribe: Drypeteae

    Drypetes arguta

    D. gerrardii

    D. natalensis

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Phyllanthus cedrifolius

Acalyphoideae

- Tribe: Clutieae

    Subtribe: Cluytieae

        Clutia pulchella

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca berberidae

        E. menyhartii

        Micrococca capensis

    Subtribe: Acalyphinae

        Acalypha glabrata var. *glabrata*

        A. glabrata var. *pilosior*

        A. sonderiana

Crotonoideae

- Tribe: Gelonieae

    Subtribe: Gelonieae

        Suregada africana

- Tribe: Crotoneae

    Groton megalobotrys

Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Sapium ellipticum

        S. integerrimum

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Euphorbia cooperi

        E. espinosa

        E. ingens

        E. tirucalli

        Synadenium cupulare

All other representatives of subfamilies contain tanniniferous cells in their bark tissues.

Tanniniferous substances and crystals are mutually exclusive in the same cell, but mutually inclusive in separate cells. Representatives of the following subfamilies contain both abundant tanniniferous cells and abundant crystals:

Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis hirta (prisms and druses)

- Tribe: Bridelieae

    Bridelia cathartica (prisms)

    B. mollis (prisms and druses)

- Tribe: Antidesmeae

    Antidesma venosum (prisms and druses)

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia (prisms and druses)

Subtribe: Flueggeinae

Flueggea virosa (prisms and druses)

Margaritaria discodea (prisms)

Phyllanthus reticulatus (prisms)

Oldfieldioideae

- Tribe: Hyaenancheae

  Subtribe: Hyaenanchinae

  Hyaenanche globosa (prisms)

- Tribe: Petalostigmateae

  Subtribe: Petalostigmatinae

  Androstachys johnsonii (prisms)

Crotonoideae

- Tribe: Aleuritideae

  Subtribe: Grosserinae

  Cavacoa aurea (prisms and druses)

Euphorbioideae

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Spirostachys africana (prisms)

It is noteworthy that, although prisms, druses or combinations of these crystals do occur in abundance with plentiful tanniniferous cells, styloids were not observed to be present in barks containing tanniniferous cells. Styloids and tanniniferous cells are mutually exclusive. It appears most probable that styloid-containing tissues contain some factor that is capable of preventing the accumulation of tanniniferous substances.

6.9 SECRETORY STRUCTURES

In this study tanniniferous cells are divorced from secretory structures. Secretory structures here include oil cells, mucilaginous (slime) cells, enlarged (sacs) tanniniferous cells, secretory ducts or canals, articulated laticifers, non-articulated laticifers and irregular systems of secretory cavities. Of all the above-mentioned secretory structures only non-articulated laticifers were encountered.

Several authors (e.g. De Bary 1884; Pax 1884; Solereder 1908; Metcalfe & Chalk 1950; Metcalfe 1967 and Fahn 1979) have described the structure of laticifers. Laticifer investigation has suffered from a confusion of terminology and interpretation of laticifer types (Rudall 1987). In this study laticifer description follows Rudall (1987).

In the large cosmopolitan family Euphorbiaceae, laticifers occur in many genera (Rudall 1987). However, in the representatives of the subfamilies studied, the position is as follows:

- Laticifers are present in representatives of subfamilies Phyllanthoideae and Oldfieldioideae.
- In subfamily Acalyphoideae there are no laticifers, except in *Macaranga capensis* that exhibits non-articulated laticifers.

- Laticifers are lacking in subfamily Crotonoideae, save *Croton sylvaticus* with non-articulated laticifers.
- Subfamily Euphorbioideae contains several representatives that contain non-articuclated laticifers, namely *Sapium integerrimum, Spirostachys africana, Euphorbia cooperi, E. espinosa, E. ingens, E. tirucalli* and *Synadenium cupulare.*

The non-articulated laticifers in subfamilies Acalyphoideae, Crotonoideae and Euphorbioideae, tribe Hippomaneae, subtribe Hippomaninae are randomly dispersed and may be occasionally branched. Those encountered in subfamily Euphorbioideae, tribe Euphorbieae, subtribe Euphorbiinae are arranged in two systems: an axial system located in the secondary phloem and a horizontal system found in the cortex. These laticifers are also occasionally branched.

6.10 MATURE PERIDERM

The mature periderm is divided into phellem (cork) and phelloderm. These two tissues are separated by the meristematic phellogen (cork cambium).

6.10.1 Phellem

Phellem cells are generally suberized. In shape they may be tangentially elongate, radially elongate or square. Their cell walls may be thickened in various ways (see The Character List, Chapter 2). In this study, *inter alia*, impregnation with lignin of phellem cells, occurrence and calcium oxalate crystals in phellem and phellem stratification were considered.

Representatives of the following subfamilies exhibit lignified phellem cells (phelloids):

Phyllanthoideae

- Tribe: Bridelieae

  Bridelia micrantha

  Cleistanthus schlecteri

- Tribe: Drypeteae

  Drypetes arguta

  D. gerrardi

  D. natalensis

- Tribe: Phyllantheae

  Subtribe: Phyllantheae

  Pseudolachnostylis maprounefolia

  Subtribe: Flueggeinae

  Margaritaria discodea

- Tribe: Hymenocardieae

  Subtribe: Hymenocardieae

  Hymenocardia ulmoides

- Tribe: Uapaceae

  Subtribe: Uapaceae

  Uapaca kirkiana

  U. sansibarica

Oldfieldioideae

- Tribe: Hyaenancheae

    Subtribe: Hyaenanchinae

        Hyaenanche globosa

Acalyphoideae

- Tribe: Clutieae

    Subtribe: Cluytieae

        Clutia pulchella

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca berberidae

        E. menyhartii

        Micrococca capensis

    Subtribe: Acalyphinae

        Acalypha glabrata var. *pilosior*

        A. sonderiana

Crotonoideae

- Tribe: Gelonieae

    Subtribe: Gelonieae

        Suregada africana

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea

- Tribe: Crotoneae

    Croton gratissimus

    C. pseudopulchellus

    C. sylvaticus

Representatives of the following subfamilies lack lignified phellem cells:

Phyllanthoideae

- Tribe: Wielandieae

    All members

- Tribe: Bridelieae

    Bridelia cathartica

    B. mollis

- Tribe: Poranthereae

    Subtribe: Poranthereae

    Andrachne ovalis

- Tribe: Antidesmeae

    Antidesma venosum

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

    Flueggea virosa

    Phyllanthus cedrifolius

    P. reticulatus

Oldfieldioideae

- Tribe: Petalostigmateae

  Subtribe: Macaranginae

  Macaranga capensis

  Subtribe: Acalyphinae

  Acalypha glabrata var. *glabrata*

Crotonoideae

- Crotoneae

  Croton megalobotrys

  C. menyhartii

Euphorbioideae

All representatives studied

Prisms are present only in phellem in subfamily Phyllanthoideae, tribe Drypeteae, *Drypetes natalensis*.

Where and when the phellem is stratified, thin-walled layers of phellem cells, alternate with thick-walled layers. Representatives of the following subfamilies exhibit such phellem zones:

Phyllanthoideae

- Tribe: Phyllantheae

  Subtribe: Flueggeinae

  Margaritaria discodea

Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Claoxylinae

  Erythrococcca berberidae

  Subtribe: Acalyphinae

  Acalypha glabrata var. *pilosior*

Crotonoideae

- Tribe: Crotoneae

  Croton menyhartii

  C. pseudopulchellus

Lignification of phellem cells within given taxa appears to follow a strong trend. This is evidenced by lignified phellem cells of most representatives of subfamily Phyllanthoideae especially within tribe Drypeteae, genus *Drypetes*; subfamily Acalyphoideae, particularly in tribe Acalypheae and subfamily Crotonoideae, especially within tribe Crotoneae. Representatives of subfamily Euphorbioideae are lumped together by their lack of lignified phellem cells.

The unique occurrence of abundant crystals (prisms) in phellem in subfamily Phyllanthoideae, tribe Drypeteae, *Drypetes natalensis* is taxonomically significant.

Stratification of the phellem appears to be inconsistent for a taxon.

6.10.2 Phelloderm

Phelloderm cells are generally arranged in radial rows, are usually isodiametric and often remain parenchymatous. Phelloderm was considered present, if it was more than three layers thick, otherwise it was pronounced absent or poorly developed.

Among other features, crystals and tanniniferous cells were considered in the phelloderm.

Well-developed phelloderm is present in representatives of the following subfamilies:

Phyllanthoideae

- Tribe: Wielandieae

  Heywoodia lucens

  Lachnostylis hirta

- Tribe: Bridelieae

  Bridelia micrantha

- Tribe: Drypeteae

    Drypetes arguta

    D. gerrardii

    D. natalensis

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia

    Subtribe: Flueggeinae

        Margaritaria discodea

        Phyllanthus cedrifolius

        P. reticulatus

- Tribe: Uapaceae

    Subtribe: Uapaceae

        Uapaca kirkiana

        U. sansibarica

Oldfieldioideae

- Tribe: Hyaenanche

    Subtribe: Hyaenanchinae

        Hyaenanche globosa

Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Macaranginae

        Macaranga capensis

Subtribe: Claoxylinae

Erythrococca berberidae

Micrococca capensis

Subtribe: Acalyphinae

Acalypha glabrata var. *glabrata*

A. sonderiana

Crotonoideae

- Tribe: Crotoneae

Croton gratissimus

C. megalobotrys

C. menyhartii

C. pseudopulchellus

Euphorbioideae

- Tribe: Hippomaneae

Subtribe: Hippomaninae

Spirostachys africana

- Tribe: Euphorbieae

Subtribe: Euphorbiinae

Synadenium cupulare

Phelloderm is absent or poorly developed in representatives of the following subfamilies:

Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis bilocularis

- Tribe: Bridelieae

    Bridelia cathartica

    B. mollis

    Cleistanthus schlecteri

- Tribe: Porantthereae

    Subtribe: Poranthereae

        Andrachne ovalis

- Tribe: Antidesmeae

    Antidesma venosum

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Flueggea virosa

- Tribe: Hymenocardieae

    Subtribe: Hymenoccardieae

        Hymenocardia ulmoides

Oldfieldioideae

- Tribe: Petalostigmateae

    Subtribe: Petalostigmatinae

        Androstachys johnsonii

Acalyphoideae

- Tribe: Clutieae

    Subtribe: Cluytieae

        Clutia pulchella

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Erythrococca menyhartii

    Subtribe: Acalyphinae

        Acalypha glabrata var. *pilosior*

Crotonoideae

- Tribe: Gelonieae

    Subtribe: Gelonieae

        Suregada africana

- Tribe: Aleuritideae

    Subtribe: Grosserinae

        Cavacoa aurea

- Tribe: Crotoneae

    Croton sylvaticus

Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

        Sapium ellipticum

        S. integerrimum

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

    Euphorbia cooperi

    E. espinosa

    E. ingens

    E. tirucalli

The following representatives of subfamilies exhibit crystals in their phelloderms:

Phyllanthoideae

- Tribe: Wielandieae

    Heywoodia lucens (abundant druses)

- Tribe: Drypeteae

    Drypetes arguta (abundant prisms)

    D. gerrardii (sparse prisms)

    D. natalensis (abundant prisms)

- Tribe: Phyllantheae

    Subtribe: Securineginae

    Pseudolachnostylis maprounefolia (abundant prisms)

    Subtribe: Flueggeinae

    Phyllanthus reticulatus (sparse prisms)

Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Claoxylinae

    Micrococca capensis (sparse prisms)

    Subtribe: Acalyphinae

    Acalypha glabrata var. *glabrata* (abundant prisms and styloids)

Crotonoideae

- Tribe: Crotoneae

    Croton megalobotrys (sparse druses)

    C. menyhartii (sparse druses)

Euphorbioideae

- Tribe: Hippomaneae

    Subtribe: Hippomaninae

    Spirostachys africana (sparse prisms)

Tanniniferous cells are present in the phelloderm of the following representatives of the subfamilies:

Phyllanthoideae

- Tribe: Wielandieae

    Lachnostylis hirta (abundant)

- Tribe: Bridelieae

    Bridelia micrantha (abundant)

- Tribe: Phyllantheae

    Subtribe: Securineginae

    Pseudolachnostylis maprounefolia (abundant)

    Subtribe: Flueggeinae

    Margaritaria discodea (abundant)

    Phyllanthus reticulatus (abundant)

- Tribe: Hymenocardieae

    Subtribe: Hymenocardieae

    Hymenocardia ulmoides (abundant)

Oldfieldioideae

- Tribe: Hyaenancheae

    Subtribe: Hyaenanchinae

    Hyaenanche globosa (abundant)

Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Macaranginae

    Macaranga capensis (abundant)

Crotonoideae

- Tribe: Crotoneae

    Croton gratissimus (sparse)

    C. menyhartii (sparse)

    C. sylvaticus (abundant)

Euphorbioideae

- Tribe: Hippomaneae

  Subtribe: Hippomaninae

  Spirostachys africana (abundant)

The presence of phelloderm is a general trend in representatives of subfamily Phyllanthoideae, especially in tribe Drypeteae, genus *Drypetes*, subfamily Acalyphoideae, tribe Acalypheae, particularly within subtribes Macaranginae, Claoxylinae and Acalyphinae, and subfamily Crotonoideae in tribe Crotoneae. Most representatives of subfamily Euphorbioideae lack a phelloderm.

Crystalliferous phelloderms typify representatives of subfamily Phyllanthoideae, tribe Drypeteae, genus *Drypetes*.

The occurrence of tanniniferous cells in phelloderms of representatives of subfamilies, does not seem to be a constant feature in any given broad taxon.

6.11 CORTEX

The cortex is a general and familiar tissue zone of young stems and roots. Cortex is usually parenchymatous or parenchymatous and collenchymatous (Esau 1977; Fahn 1982). In mature stems that have undergone secondary growth, the cortex is usually absent. If persistent, it may or may not contain crystals, tanniniferous cells and/or sclerotic elements.

Cortices are persistent in the following representatives of the subfamilies:

Phyllanthoideae

- Tribe: Wielandeae

  Lachnostylis hirta

- Tribe: Drypeteae

  Drypetes arguta

  D. gerrardii

  D. natalensis

- Tribe: Phyllantheae

  Subtribe: Securineginae

  Pseudolachnostylis maprounefolia

  Subtribe: Flueggeinae

  Phyllanthus cedrifolius

  P. reticulatus

Acalyphoideae

- Tribe: Acalypheae

  Subtribe: Claoxylinae

  Erythrococca menyhartii

  Micrococca capensis

  Subtribe: Acalyphinae

  Acalypha glabrata var. *glabrata*

  A. glabrata var. *pilosior*

  A. sonderiana

Crotonoideae

- Tribe: Crotoneae

    Croton sylvaticus

Euphorbioideae

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Euphorbia cooperi

        E. espinosa

        E. ingens

        E. tirucalli (not observed)

        Synadenium cupulare

Crystalliferous cortices occur in the following subfamilies:

Phyllanthoideae

- Tribe: Drypeteae

    Drypetes arguta (prisms)

    D. gerrardii (prisms)

    D. natalensis (prisms)

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

        Phyllanthus cedrifolius (prisms)

Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Claoxylinae

        Micrococca capensis (prisms)

    Subtribe: Acalyphinae

        Acalypha glabrata var. *glabrata* (prisms)

        A. glabrata var. *pilosior* (druses)

        A. sonderiana (druses)

Euphorbioideae

- Tribe: Euphorbieae

    Subtribe: Euphorbiinae

        Synadenium cupulare (microprisms)

Pericyclic fibres are predominantly absent. If present they are lignified, cellulosic or gelatinous. Within the following genera these phloem caps are persistent: *Acalypha, Drypetes* and *Phyllanthus*.

The following representatives of subfamilies exhibit tanniniferous cells and/or sclerotic elements (exluding primary phloem fibres) in their cortices:

Phyllanthoideae

- Tribe: Wielandeae

    Lachnostylis hirta (tanniniferous cells and idioblastic sclereids)

- Tribe: Drypeteae

    Drypetes arguta (idioblastic sclereids and small clusters of sclereids)

    D. gerrardii (scattered lignified cells)

- Tribe: Phyllantheae

    Subtribe: Securineginae

        Pseudolachnostylis maprounefolia (partly lignified cells)

    Subtribe: Flueggeinae

        P. reticulatus (tanniniferous cells)

Crotonoideae

- Tribe: Crotoneae

    Croton sylvaticus (tanniniferous cells)

Persistence of the cortex is constant in subfamily Phyllanthoideae, tribe Drypeteae, genus *Drypetes*; subfamily Acalyphoideae, tribe Acalypheae, subtribe Acalyphinae, genus *Acalypha* and in subfamily Euphorbioideae, tribe Euphorbieae, subtribe Euphorbiinae. When the cortex is persistent in other tribes and subtribes, its persistence is erratic.

Crystalliferous cortices indicate a strong trend of occurrence in subfamily Phyllanthoideae, tribe Drypeteae, genus *Drypetes* and in subfamily Acalyphoideae, tribe Acalypheae, subtribe Acalyphinae, genus *Acalypha*.

Tanniniferous cells and/or sclerotic elements in the cortex occur irregularly within the subfamilies and their sub-taxa.

6.12 SUMMARY OF INFRAGENERIC VARIATION

Under this subtopic major bark anatomical differences between species within each selected genus will be noted.

Subfamily Phyllanthoideae

- Tribe: Wielandieae

  Genus: *Lachnostylis*

  Species: *L. bilocularis* — dilatation tissue absent, fibres predominant, axial chambered crystalliferous strands associated with sclerenchyma, phelloderm absent, cortex absent.

  Species: *L. hirta* — dilatation tissue present, fibres not predominant, axial chambered crystalliferous strands randomly dispersed, phelloderm present, cortex persistent.

- Tribe: Bridelieae

  Genus: *Bridelia*

  Species: *B. cathartica* — dilatation tissue absent, fibres only, prisms and druses, phellem cells unlignified, phelloderm absent.

  Species: *B. micrantha* — dilatation tissue present, fibres and sclereids, prisms and druses, phellem cells lignified, phelloderm present.

  Species: *B. mollis* — dilatation tissue present, fibres only, prisms only, phellem cells unlignified, phelloderm absent.

- Tribe: Drypeteae

    Genus: *Drypetes*

    Species: *D. arguta* — sclereids and fibre-sclereids, sclereids predominant, prisms only, axial chambered crystalliferous strands randomly dispersed.

    Species: *D. gerrardii* — fibres, sclereids and fibre-sclereids, prisms and druses, axial chambered crystalliferous associated with sclerenchyma and randomly dispersed.

    Species: *D. natalensis* — fibres and sclereids, prisms only, axial chambered crystalliferous strands associated with sclerenchyma and randomly dispersed, phellem with prisms.

- Tribe: Phyllantheae

    Subtribe: Flueggeinae

    Genus: *Phyllanthus*

    Species: *P. cedrifolius* — dilatation tissue absent, sclereids and fibre-sclereids, tanniniferous cells absent.

    Species: *P. reticulatus* — dilatation tissue present, sclereids only, tanniniferous cells present.

Subfamily: Acalyphoideae

- Tribe: Acalypheae

    Subtribe: Claoxylinae

    Genus: *Erythrococca*

    Species: *E. berberidae* — sclerenchyma absent, styloids only, phellem stratified, cortex absent.

Species: *E. menyhartii* — sclerenchyma present, styloids and prisms, phellem unstratified, cortex present.

Subtribe: Acalyphinae

Genus: *Acalypha*

Species: *A. glabrata*

Variety: *glabrata* — sclereids only, styloids and prisms, axial chambered crystalliferous strands absent, phellem cells unlignified, cortex with prisms.

Variety: *pilosior* — sclerenchyma absent, druses only, axial chamberd crystalliferous strands randomly dispersed, phellem cells lignified, cortex with druses.

Species: *A. sonderiana* — sclereids and fibre-sclereids, druses and prisms, axial chambered crystalliferous strands associated with sclerenchyma, lignified phellem cells, cortex with druses.

6.13 DICHOTOMOUS KEY TO SPECIES STUDIED

NOTE: Unless stated otherwise, reference to 'sclerenchyma/fibres/sclereids' in the key, refers to elements contained in those parts of the secondary phloem not affected by dilatation growth. 'Crystals/prisms/druses/styloids' refer to crystal forms of calcium oxalate. Owing to the difficulties encountered in sectioning the bark of *Uapaca* species, which resulted in poor quality microscope slides, these species have been omitted from the key.

1a Sclerenchyma well developed (walls of elements notably thickened) 10

1b Sclerenchyma absent, or very poorly developed (then walls of elements not notably thickened) 2

2a Crystals present 6

2a Crystals absent 3

3a Laticifers present, cortex persistent 4

3b Laticifers absent, cortex absent . . . . *Clutia pulchella*

4a Phloem parenchyma with locally slightly lignified patches (cell walls not notably thickened) . . . . *Euphorbia cooperi*

4b Phloem parenchyma not lignified 5

5a Phelloderm well developed . . . . *Euphorbia espinosa*

5b Phelloderm absent, or poorly developed . . . . *Euphorbia ingens*

6a Styloids present 7

6b Styloids absent 8

7a Prisms present; cortex persistent . . . . *Micrococca capensis*

7b Prisms absent; cortex absent . . . . *Erythrococca berberidae*

8a Chambered crystalliferous strands present . . *Acalypha glabrata* var. *pilosior*

8b Chambered crystalliferous strands absent 9

9a Druses present, laticifers absent . . . . *Suregada africana*

9b Druses absent, laticifers present . . . . *Synadenium cupulare*

10a Crystals present 11

10b Crystals absent . . . . *Andrachne ovalis*

11a Crystals exclusively prisms 12

11b Crystals comprising prisms and druses 23

12a Chambered crystalliferous strands present 13

12b Chambered crystalliferous strands absent 18

13a Fibres present 15

13b Fibres absent 14

14a Dilatation tissue well developed; cortex persistent . . . . *Drypetes arguta*

14b Dilatation tissue poorly developed; cortex absent . . . *Hymenocardia ulmoides*

15a Sclerenchyma exclusively fibres . . . . *Bridelia mollis*

15b Sclerenchyma not exclusively fibres 16

16a Phellem crystalliferous; tanniniferous cells absent . . . . . *Drypetes natalensis*

16b Phellem not crystalliferous; tanniniferous cells present 17

17a Phloem rays exclusively uniseriate . . . . *Androstachys johnsonii*

17b Phloem rays not exclusively uniseriate . . . . *Hyaenanche globosa*

18a Sclereids present 20

18b Sclereids absent 19

19a Fibres exclusively cellulosic . . . . *Spirostachys africana*

19b Fibres not exclusively cellulosic . . . . *Euphorbia tirucalli*

20a Fibres present 21

20b Fibres absent 22

21a Prisms abundant, forming axial strands associated with sclerenchyma; prisms absent in phloem rays . . . . *Sapium ellipticum*

21b Prisms sparse, randomly dispersed; prisms present in phloem rays . . . . *Sapium integerrimum*

22a Sclerenchyma scattered in small randomly dispersed clusters; dilatation tissue absent; tanniniferous cells absent . . . *Phyllanthus cedrifolius*

22b Sclerenchyma forming irregular compact groups; dilatation tissue well developed; tanniniferous cells present . . . . *Phyllanthus reticulatus*

23a Chambered crystalliferous strands present 29

23b Chambered crystalliferous strands absent 24

24a Sclereids present 25

24b Sclereids absent . . . . *Cleistanthus schlecteri*

25a Styloids present 26

25b Styloids absent 27

26a Fibres present; cortex without prisms . . . . *Erythrococca menyhartii*

26b Fibres absent; cortex with prisms . . . . *Acalypha glabrata* var. *glabrata*

27a Phelloderm crystalliferous; fibres absent . . . . *Heywoodia lucens*

27b Phelloderm not crystalliferous; fibres present 28

28a Dilatation tissue well developed; lignified phellem cells present,

cortex persistent . . . . *Croton sylvaticus*

28b Dilatation tissue absent; lignified phellem cells absent;

cortex absent . . . . *Antidesma venosum*

29a Tanniniferous cells present 32

29b Tanniniferous cells absent 30

30a Fibres present 31

30b Fibres absent . . . . *Acalypha sonderiana*

31a Lignified phellem cells present; cortex persistent . . . . . . *Drypetes gerrardii*

31b Lignified phellem cells present; cortex absent . . . . . . *Croton megalobotrys*

32a Sclereids present 33

32b Sclereids absent . . . . *Bridelia cathartica*

33a Prisms present 36

33b Prisms absent 34

34a Chambered crystalliferous strands associated with sclerenchyma . . . . *Margaritaria discoidea*

34b Chambered crystalliferous strands not associated with sclerenchyma 35

35a Cortex persistent . . . . *Pseudolachnostylis maprounefolia*

35b Cortex absent . . . . *Cavacoa aurea*

36a Cortex persistent . . . . *Lachnostylis hirta*

36b Cortex absent 37

37a Dilatation tissue well developed 38

37b Dilatation tissue absent . . . . *Lachnostylis bilocularis*

38a Phelloderm present, well developed 39

38b Phelloderm absent or poorly developed . . . . *Flueggea virosa*

39a Phellem stratified 40

39b Phellem not stratified 41

40a Tanniniferous cells restricted to dilatation tissue . . . *Croton pseudopulchellus*

40b Tanniniferous cells not restricted to dilatation tissue . . . . *Croton menyhartii*

41a Gelatinous fibres present . . . . *Bridelia micrantha*

41b Gelatinous fibres absent 42

42a Tanniniferous cells abundant throughout bark, except in phellem . . . . *Macaranga capensis*

42b Tanniniferous cells sparse, occur mainly in dilatation tissue and phelloderm . . . . *Croton gratissimus*

CHAPTER 7

DISCUSSION AND CONCLUSIONS

7.1 INTRODUCTION

In an effort to discover cogent taxonomic pointers to circumscribe and delimit the Euphorbiaceae and its infrafamilial taxa, early taxonomists used conventional criteria such as vegetative features, floral morphology and fruit type. To establish infrafamilial relationships, modern workers have used, *inter alia*, pollen morphology (Punt 1962; Levin & Simpson 1994; Nowicke 1994); inflorescence structure (Airy Shaw 1965), chromosome number (Hans 1973); seed structure (Corner 1976) phytochemistry (Gibbs 1974; Hegnauer 1977; Rizk 1987; Siegler 1994); laticifers (Rudall 1987, 1994); wood anatomy (Metcalfe & Chalk 1950; Mennega 1987; Hayden 1994) and embryology (Kapil & Bhatnagar 1994). Some of the findings have led to the recognition of segregate families (Table 2), while other discoveries have confirmed relationships between some taxa of the family.

In contradistinction to wood anatomy as a source of taxonomic evidence, bark has received little attention, save the work of Roth (1981). To resolve the controversy of infrafamilial relationships within the Euphorbiaceae, it is essential that data should be gleaned from all taxonomically relevant fields of knowledge, including from the microscopic structure of bark cells and tissues. The present study is attempting to contribute towards this ideal.

In this chapter, the DELTA character list, taxonomic significance of the investigated bark characters, bark anatomy and the classification of the Euphorbiaceae and the diagnostic potential of bark anatomy to establish the identity of bark samples, will be discussed.

7.2 THE CHARACTER LIST

For the first time a comprehensive bark anatomical character list was compiled. The list was tested by using a few hundred microscopic slides which were prepared from collected bark samples of various southern African Euphorbiaceae.

The character list was adapted to the DELTA computer programme. This programme makes it possible to generate comparable bark anatomical descriptions. The list is easy to use and allows for describing many samples in a relatively short time.

The character list is meant for universal use for all woody plant specimens, and as such it is hoped to be an important tool to assist future workers. The character list was repeatedly refined until it assumed its present form as presented in Chapter 2 (2.6.10).

7.3 TAXONOMIC SIGNIFICANCE OF BARK ANATOMICAL CHARACTERS

In this study the following observations and conclusions were made and arrived at respectively. These refer to the investigated Euphorbiaceae only.

7.3.1 Axial phloem parenchyma

All features of axial phloem parenchyma were found to be almost constant for all taxa. Consequently axial phloem parenchyma is taxonomically insignificant at infrafamilial levels.

7.3.2 Phloem rays

Phloem rays were found to be poor taxonomic indicators.

The width of rays is predominantly 1—3-seriate, rarely 1—5-seriate (*Antidesma venosum* and *Cleistanthus schlecteri*). These two genera are unrelated as they belong to two different tribes. Rays are exclusively uniseriate in *Androstachys johnsonii*. This is one bark anatomical character that may support the segregation and elevation of this genus to the Androstachydaceae. The latter family is recognized by Airy Shaw (1965) and Meeuse (1990).

7.3.3 Sclerenchyma

The presence or absence of sclerenchyma is not constant for any of the suprageneric taxa studied. Where sclerenchyma is present in such a taxon, the type of sclerenchyma may differ. As a result sclerenchyma alone does not distinguish any suprageneric taxon.

According to Roth (1981), fibres are more common, especially in the barks of tropical trees, than sclereids. Of all species she studied, 80% contained fibres. In the present study, of all species investigated, only 52% contain fibres, while 66% contain sclereids. Roth (1981) attributes this disparity to the fibre being a relatively primitive and an original character in the phloem of dicotyledons. She further assumes that tropical trees show more primitive characters than trees of 'temperate' regions or extreme habitats. Parameswaran & Liese (1970) state that fibres occur more frequently in tropical trees than in Central European trees.

Fibres are predominantly non-septate. The fact that they are septate in *Drypetes natalensis* only, may be of taxonomic importance. Further study of the relationship between this species and other members of the genus is required. Fibre-sclereids were observed not to be present alone in any taxon, but always associated with sclereids and/or fibres.

7.3.4 Dilatation Tissue

The presence of a well developed dilatation tissue is of taxonomic importance. This is evidenced by the presence of dilatation tissue in all related genera falling under subfamilies Acalyphoideae and Crotonoideae. In these two subfamilies, all the genera display a well developed dilatation tissue. However, this trend is not constant in other subfamilies.

7.3.5 Calcium oxalate crystals

Prisms and/or druses of calcium oxalate occur in representatives of all subfamilies, but styloids are restricted to the subfamily Acalyphoideae. Occurrence of different combinations of crystals are characteristic of certain genera. The presence of a particular type of crystal is also diagnostic for some genera. Crystals are, therefore, of considerable taxonomic significance.

7.3.6 Axial chambered crystalliferous strands

Presence or absence of axial crystalliferous strands is distinctive of tribes and genera. For instance, all tribes in subfamily Euphorbioideae lack axial crystalliferous strands, whereas in subfamily Phyllanthoideae, all representatives of tribe Drypeteae exhibit such strands. Association or non-association of axial crystalliferous strands with sclerenchyma is characteristic of certain genera. The type of sclerenchyma with which these strands are associated, is also characteristic at the generic level. Axial crystalliferous strands are thus taxonomically significant.

7.3.7 Tanniniferous cells

The occurrence of tanniniferous cells is erratic within taxa, consequently these cells are usually of no taxonomic value. However, absence of tanniniferous cells in representatives of a particular taxon may indicate taxonomic relationships (e.g. tribes Drypeteae, Hippomaninae and Euphorbieae).

7.3.8 Secretory structures

Representatives of subfamily Euphorbioideae (tribe Euphorbieae, subtribe Euphorbiinae) are, amongst other characters, bound together by possessing laticifers. Laticifers here are of taxonomic significance, because they clearly indicate phylogenetic relationship.

7.3.9 Mature Periderm

- ***Phellem***

Lignification of phellem cells is constant in tribe Drypeteae and certain apparently unrelated genera. For this tribe, lignification of phellem cells is diagnostic, otherwise it is characteristic of those genera which exhibit this feature. Crystals (prisms) of calcium oxalate are absent in the phellem of all taxa studied, except in subfamily Phyllanthoideae, tribe Drypeteae, *Drypetes natalensis*. This is an important diagnostic character for this species.

- ***Phelloderm***

The occurrence of phelloderm is sporadic within genera and suprageneric taxa. The tendency is that where a well developed phellem is present, the phelloderm is absent or poorly developed. When phelloderm is well developed it is usually diagnostic at the species level.

7.3.10 Cortex

The cortex is generally absent in mature bark. When it is still present in older stems, like in tribe Drypeteae and subtribe Acalyphinae, it is of diagnostic value.

7.4 BARK ANATOMY AND THE CLASSIFICATION OF THE EUPHORBIACEAE

7.4.1 Introduction

The classification of the Euphorbiaceae has been and still is debatable and controversial. Consequently many workers have attempted to resolve this controversy from different angles relevant to the taxonomy of the family.

In April 1986, a symposium was held on the Euphorbiales at the Jodrell Laboratory, Royal Botanic Gardens, Kew. This symposium focussed on various aspects of the Euphorbiales, such as chemistry, taxonomy and economic botany of the taxa (Jury *et al.* 1987).

In August 1989, the first International Conference on the Systematics of the Euphorbiaceae was held at the Missouri Botanical Garden in St Louis. Although many papers were read at the conference, the taxonomic significance of bark anatomy was not considered (Webster 1994).

As the present study is the first significant contribution to the taxonomic significance of bark anatomy in the Euphorbiaceae, and as the number of taxa investigated in this study are limited in relation to the enormous size of the family, definite specific and generalized statements cannot be enunciated. However, certain bark anatomical characters of potential taxonomic significance will be highlighted below.

7.4.2 Family and segregate families

On the basis of bark anatomical features, the investigated Euphorbiaceae approximates an apparently close-knit taxonomic unit. Representatives of the various subfamilies share many bark anatomical features (see Table 6).

The classification of the Euphorbiaceae according to conventional taxonomic criteria, however, is controversial. The debatable infrafamilial classification of this family has, for example, led to the proposal of segregate families (see Table 2).

The type genus *Androstachys* (in particular *A. johnsonii*) of the Androstachydaceae, is only unique in containing exclusively uniseriate phloem rays in the bark. Otherwise its bark anatomy displays many features that support its placement in the Euphorbiaceae. In 1970 Airy Shaw described four new species from Madagascar: *Androstachys imberbis* Airy Shaw, *A. merana* Airy Shaw, *A. rufibarbis* and *A. viticifolia* (Radcliffe-Smith 1987). It would be informative to see whether these species also display uniseriate rays or not. Embryological studies by Kapil & Bhatnagar (1994) place *Androstachys* Prain in subfamily Oldfieldioideae of the Euphorbiaceae. According to Levin & Simpson (1994), *Androstachys* is a *bona fide* member of the Oldfieldioideae rather than belonging to a family of its own.

Although *Drypetes natalensis* is exceptional in containing septate fibres and calcium oxalate crystals in the phellem, it shares various bark anatomical features with other *Drypetes* spp., as well as other Euphorbiaceae taxa studied. Consequently the placement of *Drypetes* in a separate family, Putranjivaceae, is not supported by bark anatomy. The wood anatomy of *Putranjiva* and *Drypetes* is similar (Mennega 1987). Further, Kapil & Bhatnagar (1994) on embryological evidence, place *Putranjiva* in tribe Drypeteae, subfamily Phyllanthoideae, family Euphorbiaceae, a position supported by bark anatomy.

Hymenocardia, sometimes placed in the segregate family Hymenocardiaceae, has many palynological features found in the Phyllantoideae and should be retained in the Euphorbiaceae in that subfamily (Levin & Simpson 1994). The findings of the present study are in agreement with this view.

The investigated *Phyllanthus* species share many bark anatomical features with other taxa of the Phyllanthoideae. In different studies, Jensen *et al.* (1994) and Kapil & Bhatnagar (1994) also retained *Phyllanthus* in subfamily Phyllanthoideae, family Euphorbiaceae.

On the basis of anatomical (Hayden 1994), embryological (Kapil & Bhatnagar 1994) and palynological (Levin & Simpson 1994) studies, Webster (1994) concluded that controversial genera such as *Antidesma*, *Bishofia* and *Hymenocardia* are nested within Euphorbiaceae. With regard to *Antidesma* and *Hymenocardia* no 'non-euphorbiaceous' bark anatomical features were observed that warrant placing these taxa in segregate families.

The monogeneric family Uapacaceae, based on *Uapaca*, was recognized by Kew for some time, but Kew has now revoked that decision (Radcliffe-Smith 1987). On the basis of wood anatomy, Metcalfe & Chalk (1950) could not readily fit *Uapaca* into their main euphorbiaceous groups. However, palynologically *Uapaca* has a pollen type similar to genera of the tribe Phyllantheae (Hans 1973). Webster (1975, 1987) has placed *Uapaca* at tribal level in subfamily Phyllanthoideae, family Euphorbiaceae. From the scanty information gleaned from the present study, no observations were made to support the elevation of this taxon to family level.

Available evidence does not support the recognition of most of the segregate families listed in Table 2. Hence, despite proposals for segregate families, Webster (1994) considers the Euphorbiaceae (*s.l.*) to be monophyletic.

7.4.3 **Subfamilies**

Bark anatomical characters shared by all five subfamilies of the Euphorbiaceae, include the presence of dilatation tissue, sclerenchyma and calcium oxalate crystals in most representatives studied. Several chemical characters, such as triterpenes, also serve to link the five subfamilies (Siegler 1994). According to the present level of embryological information, classification of the Euphorbiaceae into five subfamilies is substantiated (Kapil & Bhatnagar 1994).

Individual subfamilies exhibit definite trends in the occurrence of one or more bark anatomical characters. These trends are possibly pointers to the interrelationships between taxa within the subfamilies. The following observations support this statement:

- In subfamily Phyllanthoideae, there are strong tendencies towards the occurrence of sclerenchyma, (notably sclereids), calcium oxalate crystals (especially prisms) and chambered crystalliferous strands, mostly of the type associated with sclerenchyma. These bark anatomical characters possibly unite taxa within this subfamily. The Phyllanthoideae are also linked by tyrosine derived cyanogens (Siegler 1994). Foliar venation *sensu* Levin (1986a, b, c) provides systematically valuable characters in this subfamily (Webster 1994).

- Although, in this study, subfamily Oldfieldioideae was represented by only two tribes with two species, there are discernable trends. These include the occurrence of a well developed dilatation tissue, fibres, prisms and chambered crystalliferous strands that are associated with sclerenchyma. Cortex is not persistent in older stems in this subfamily.

  Although the Oldfieldioideae have been insufficiently studied (Siegler 1994), they are characterized by certain features such as spiny pollen and definite morphological and anatomical characters (Hayden 1994).

- Trends within subfamily Acalyphoideae include strong tendencies towards occurrence of a well developed dilatation tissue, a well developed phelloderm and calcium oxalate crystals, particularly styloids that only occur in this subfamily. On the basis of bark anatomy of the investigated species the occurrence of styloids is considered characteristic of the Acalyphoideae. According to Siegler (1994), the Acalyphoideae is chemically typified by nicotinic acid derived cyanogens.

- Subfamily Crotonoideae is predominantly characterized by prisms and druses, as well as a well developed dilatation tissue. The subfamily also exhibits strong tendencies towards occurrence of fibres, sclereids, chambered crystalliferous strands associated with sclerenchyma, phellem with lignified cells and a well developed phelloderm.

  Nowicke (1994) presents pollen data from electron microscopy in support of the present concept of the Crotonoideae *sensu* Webster. She further states that the Crotonoideae have surprisingly uniform pollen morphology. All the cyanogens of the Crotonoideae are valine/isoleucine derived (Siegler 1994).

- Subfamily Euphorbioideae taxa exhibit strong trends towards occurrence of a well developed dilatation tissue and non-articulated laticifers in the bark. Rudall (1987) states that laticifers are present in all tribes of the Euphorbioideae. Succulent and spiny forms of the Euphorbiaceae are largely restricted to the Euphorbioideae (Meeuse 1990). According to Nowicke (1994), pollen morphology certainly does not argue against the present concept of Euphorbiodeae *sensu* Webster.

  Most authors consider the Euphorbiaceae as comprising five subfamilies. However, Jensen (1994) suggests that on the basis of serological data there appear to be two main groups of Euphorbiaceae: Phyllanthoideae + Oldfieldioideae and Acalyphoideae + Crotonoideae + Euphorbioideae (Webster 1994).

7.4.4 Tribes

The investigated species are not well spread enough within all tribes of the subfamilies. Consequently provision for cogent and meaningful systematic deductions can barely be made at tribal level. However, the following observations may be relevant:

- All represented tribes of the Phyllanthoideae exhibit sclerenchyma, mostly sclereids. Calcium oxalate crystals are predominantly prisms. The majority of the taxa contain chambered crystalliferous strands. The other bark anatomical characters are erratic in occurrence.

  Representatives of tribe Bridelieae predominantly exhibit lignified fibres together with gelatinous fibres, prisms, druses and multiple periderms. Tribe Drypeteae appears to be close-knit since all its representatives contain most of the bark anatomical characters summarized in Table 6.

- The two tribes of the Olfieldioideae both contain dilatation tissue, fibres, prisms and chambered crystalliferous strands.

- All represented tribes of the Acalyphoideae exhibit well developed dilatation zones and phelloderms. Tribe Clutieae is unique in lacking sclerenchyma and calcium oxalate crystals. The Acalypheae is the only tribe that has members with styloids.

- All investigated tribes of the Crotonoideae contain taxa with a well developed dilatation tissue, prisms and druses. The tribe Crotoneae is almost homogeneous, because nearly all of the selected bark anatomical characters occur in all members (see Table 6).

- The two representative tribes of the Euphorbioideae boast members with well developed dilatation tissue zones. All representatives of tribe Hippomaninae contain sclerenchyma, while almost all members of tribe Euphorbieae lack this strengthening tissue.

The different tribes of the various subfamilies show interrelationships within each subfamily. This is evidenced by common occurrence of tribe distinguishing characters, such as a well developed dilatation tissue, sclerenchyma and calcium oxalate crystals. Tribes also differ sufficiently to deserve their tribal taxonomic status. Pertinent cases in point are the unique occurrence of styloids in tribe Acalypheae and the almost homogeneity of tribes Drypeteae and Crotoneae.

7.4.5 Subtribes

In the classification of Webster (1975, 1987) the majority of tribes are not divided into subtribes. Some tribes are divided into subtribes that contain one genus each. However, in the few tribes that are split into subtribes, the following may assist to distinguish between subtribes: sclerenchyma (presence/absence, type, dominant type) calcium oxalate crystals (presence/absence, type, dominant type) and chambered crystalliferous strands (presence/absence, randomly dispersed/associated with sclerenchyma).

7.4.6 Genera and species

On the basis of bark anatomy distinction between genera is possible [see Chapter 6 (6.13)].

Infrageneric or specific variation manifests itself in almost all bark anatomical characters (see Table 6). Consequently bark anatomy is useful at the specific level for identification, authentication or contradiction [also see Chapter 6 (6.12) and (6.13)].

7.4.7 Infraspecific variation

Striking infraspecific variation in certain bark anatomical features was noted in the varieties of *Acalypha glabrata* [see Chapter 6 (6.12)].

Among others, the following characters may show some infraspecific variation: type of dilatation tissue; occurrence, type and distribution of sclerenchyma; occurrence, type and location of calcium oxalate crystals; occurrence, quantity and distribution of tanniniferous cells; lignification of phellem cells; occurrence of phelloderm and persistence of the cortex.

7.5 DIAGNOSTIC POTENTIAL OF BARK ANATOMY

Information which enables anatomical identification of bark fragments has various applications. Among others, are the following:

- Taxonomic refinement of current classification systems. In the present study, for instance, representatives of subtribe Claoxylinae were observed to be constant in containing styloids, those of subtribe Acalyphinae all contain cortices and all those of tribe Crotoneae, genus *Croton* contain dilatation tissue, fibres, sclereids, prisms, druses and phelloderm. Bark characters may be employed as taxonomic criteria at various levels of the taxonomic hierarchy, although it appears to be most useful at the specific and generic levels.

- In southern Africa, tree bark plays an important role in traditional medicine. There is usually no way of knowing that the bark sold under a certain name is actually the correct species. An accurate identification system could form the basis of a quality control programme for the sale of bark. There is currently no reliable means of identifying bark samples traded on the open market.

- There is a need for reference collections of bark samples/slides and a data base of bark anatomical characters to enable identifications of unknown bark samples through anatomical analysis. The present study has initiated such a data base that could confirm or contradict identifications. Such a facility could, for example, help at forensic laboratories dealing with court cases involving criminal use of traditional medicines.

In conclusion the following need mention:

- Dilatation tissue and sclerenchyma not affected by dilatation growth may be diagnostic at subfamily level.

- Sclerenchyma and crystals may be diagnostic for certain tribes, subtribes and generally within subfamilies.

- Differences may occur in dilatation tissue, sclerenchyma, crystals, axial crystalliferous strands, phellem, phelloderm and cortex at specific and infraspecific levels.

The following objectives of the present study were realized:

- A comprehensive character list to facilitate bark anatomical descriptions of all woody plants, using the DELTA computer programme, was developed and tested (Chapter 2).

- Detailed bark anatomical descriptions for several southern African members of the Euphorbiaceae are provided (Chapter 5).

- Although the usefulness of bark anatomical characters for identifying medicinal bark samples was not tested as such, the present study clearly indicates that bark anatomy provides several characters that could be employed for diagnostic purposes, particularly at the generic and specific levels.

- An evaluation of the taxonomic significance of bark anatomical features at various levels of the taxonomic hierarchy in southern African Euphorbiaceae is presented in Chapter 6 and partly in the present chapter. Bark anatomy does not significantly contribute to classification at higher levels of the taxonomic hierarchy, but it is useful for identification at lower levels.

SUMMARY

THE TAXONOMIC SIGNIFICANCE OF BARK STRUCTURE IN SOUTHERN AFRICAN EUHPORBIACEAE

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The main aims of this study were to develop and compile a bark anatomical character list suitable for generating bark anatomical descriptions using the DELTA computer programme, and to use this tool to assess the taxonomic significance of bark structures in some southern African members of the Euphorbiaceae. For light microscopic study, sections were prepared from bark samples of 44 species representing 27 genera.

A universally applicable bark anatomical character list was compiled, tested and refined. The character list is usable in the DELTA computer programme. This made possible, for the first time, comprehensive descriptions of bark anatomical characters for the investigated southern African Euphorbiaceae.

A brief review of the suprageneric classification of the Euphorbiaceae is presented. Due to its enormous size and immense diversity, the classification of this family is still controversial. For this study the infrafamilial classification of Webster (1975, 1987) was followed.

In southern Africa many members of the Euphorbiaceae are of economic and traditional impor-

tance to local residents. Bark in particular is extensively used medicinally. Succulent tree members abound in subfamily Euphorbioideae, all of which contain toxic latex.

In this dissertation bark anatomical descriptions are arranged alphabetically according to species, together with diagrammatic presentations of the various bark structures. Because of problems encountered with the sectioning of bark of *Uapaca* spp. and succulent *Euphorbia* spp., only brief anatomical descriptions of these taxa are provided. The variation of selected characters are summarized in tables and the taxonomic significance of the various bark tissues and cells is discussed. Character states and taxa are listed in a way that may be used as a type of synoptic key.

Various bark characters were found to be of taxonomic importance. These include features of the dilatation tissue, sclerenchyma and calcium oxalate crystals for subfamilies; sclerenchyma and crystals for tribes; and the predominant type of calcium oxalate crystal for subtribes. Interspecific variation is chiefly reflected by presence/absence and type of sclerenchyma or crystals. Infraspecific variation relates to features of dilatation tissue, sclerenchyma, crystals, tanniniferous cells, phellem, phelloderm and the cortex.

Except for the unique uniseriate phloem rays in *Androstachys johnsonii* (Androstachydaceae) and the excèptional occurrence of septate fibres in the phloem, and prisms in the phellem of *Drypetes natalensis* (Putranjivaceae), no bark anatomical features appear to support the recognition of the various segregate families proposed by previous workers. Bark anatomy holds great potential for the refinement of current classification systems, since bark characters may be employed as taxonomic criteria at various levels of the taxonomic hierarchy, although especially in lower ranks.

The correct identity of traditional bark medicines sold to unsuspecting patients by traditional healers could be verified by anatomical investigation. Precise identification of unknown bark samples could also assist in forensic matters. Doubtful identifications of woody plants could be negated with certainty or confirmed where a data base (anatomical descriptions and authentic slide collection) of various bark samples is available. This study is a first step towards the establishment of such a data base in southern Africa.

OPSOMMING

DIE TAKSONOMIESE BETEKENIS VAN BAS-STRUKTUUR BY SUIDER-AFRIKAANSE EUPHORBIACEAE

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Die hoofdoel van hierdie ondersoek was om 'n lys van bas-anatomiese kenmerke vir gebruik met die DELTA-rekenaarprogram op te stel en dit vervolgens te gebruik om die taksonomiese betekenis van baskenmerke by die Suider-Afrikaanse Euphorbiaceae te bepaal. Vir ligmikroskopiese ondersoek is sneë van basmonsters verteenwoordigend van 44 spesies en 27 genusse voorberei.

'n Universeel-bruikbare lys basanatomiese kenmerke is opgestel, getoets en verfyn. Die kenmerklys is geskik vir gebruik met die DELTA-rekenaarprogram. Met behulp van hierdie lys is daar vir die eerste keer omvattende beskrywings van die basanatomie van die ondersoekte Suider-Afrikaanse Euphorbiaceae opgestel.

'n Kort oorsig van die suprageneriese klassifikasie van die Euphorbiaceae word verskaf. Weens sy grootte en buitengewone diversiteit, is die klassifikasie van dié familie steeds omstrede. Vir die doeleindes van die huidige ondersoek is die familieklassifikasie soos voorgestel deur Webster (1975, 1987) as grondslag gebruik.

Vir die inwoners van Suider-Afrika is talle verteenwoordigers van die Euphorbiaceae van ekono-

miese en tradisionele belang. Dit is veral bas wat op groot skaal vir medisinale doeleindes benut word. Die gebied is veral ryk aan sukkulente bome met giftige melksap, almal lede van die subfamilie Euphorbioideae.

In hierdie proefskrif word basanatomiese beskrywings wat alfabeties volgens takson gerangskik is, verskaf, asook diagrammatiese voorstellings van die onderskeie taksons se basstruktuur. Weens probleme wat met die maak van sneë van *Uapaca*- en sukkulente *Euphorbia*-spesies ondervind is, word met bondige beskrywings vir hierdie taksons volstaan. Variasie van geselekteerde kenmerke word in tabelvorm verskaf, terwyl die taksonomiese betekenis van die onderskeie sel- en weefseltipes bespreek word. Kenmerkstate en taksons word op sodanige wyse gelys dat dit as 'n tipe sinoptiese sleutel gebruik kan word.

Verskeie baskenmerke van taksonomiese belang is gevind. Dit sluit in aspekte van die uitsettingsweefsel, sklerenchiem en kalsiumoksalaat-kristalle vir subfamilies; sklerenchiem en kristalle vir tribusse; en die oorwegende tipe kalsiumoksalaat-kristal vir subtribusse. Interspesifieke variasie word hoofsaaklik deur die aan-/afwesigheid en tipe sklerenchiem of kristalle gereflekteer. Infraspesifike variasie manifisteer in aspekte van die uitsettingsweefsel, sklerenchiem, kristalle, tannienhoudende selle, felleem, felloderm en die korteks.

Met die uitsondering van die uniseriale phloeëmstrale by *Androstachys johnsonii* (Androstachydaceae) en die ongewone voorkoms van gesepteerde vesels in die phloeëm en prismatiese kristalle in die felleem van *Drypetes natalensis* (Putranjivaceae), is geen ooglopende anatomiese kenmerke gevind wat die onderskeie splinterfamilies wat deur vorige werkers voorgestel is, ondersteun nie. Basanatomie toon groot belofte as 'n hulpmiddel by die verfyning van klassifikasiestelsels, veral omdat sodanige kenmerke oor die hele spektrum van die taksonomiese rangorde gebruik kan word, alhoewel veral in die geval van die laer range.

Die korrekte identiteit van tradisionele basmedisynes wat deur tradisionele praktisyns aan niksvermoedende pasiente verskaf word, kan deur middel van anatomiese ondersoek gekontroleer word. Die presiese identifisering van onbekende baseksemplare kan ook van nut wees in die geval van forensiese ondersoeke. Die beskikbaarheid van 'n geskikte databasis (anatomiese beskrywings en 'n versameling betroubaar-benaamde mikroskooppreparate) sou kon bydra om basidentifikasies te ondersteun/bevestig, of ten minste met sekerheid te weerspreek. Hierdie ondersoek is 'n eerste stap tot die vestiging van sodanige databasis in Suider-Afrika.

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CURRICULUM VITAE

James Phumile Mtombeni was born at Payneville in Springs, on 21 April 1940, where he obtained his primary education. He received secondary education at Wilberforce Training Institute in Vereeniging and matriculated at St. Francis College in Mariannhill, Pinetown in 1960.

In 1961 he enrolled as a BSc degree student at the erstwhile Pius XII University College at Roma in Lesotho. He completed the BSc degree at the then University College of the North at Turfloop in Pietersburg. In 1965, he had a stint for a year as a laboratory assistant at Masonite (Africa) Ltd in Estcourt.

The following year he found employment as a Senior Laboratory Assistant at the then University College of Zululand in Mtunzini. After a year or so he registered as a part-time student for the BSc (Hons) degree in Botany. Having obtained the said degree he was promoted to a lectureship post.

While serving as a lecturer, he registered for the MSc degree in Botany. The research for the MSc degree landed him at the Institut für systematische Botanik der Universität München; Kew Herbarium and Library (London); Jodrell Laboratory (London); British Museum (Natural History) (London) and the Department of Forestry, University of Oxford. On his return to South Africa, he completed the MSc degree and was thereafter promoted to the post of Senior Lecturer, a post that he held until he left the University of Zululand.

In 1983, he took a teaching post as Head of Department (Mathematics and Natural Science) at Kenneth Masekela High School in Springs. He left the high school in 1986, when he found employment at the Further Training Campus (Vista University) as a lecturer, a post that he is still holding to date.

While in the employ of Vista University, he obtained an HED (post-graduate) (Unisa). He is co-author to two tertiary education textbooks in Biology. Besides other local conferences, symposia, seminars and teacher-in-service sessions, he has had occasion to attend and present a paper and a poster at an international conference in Malawi. He is also presently, an Internal Moderator of Standard 10 Biology (HG and SG) for the National Senior Certificate.

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PART 2

TABLES & FIGURES

NOTES

Part 2 contains all tables and figures referred to in Part 1.

- Figure 1 is a schematic presentation of a transverse section of a tree trunk to show the location of the various bark tissues.

- Figures 2—41 are schematic presentations (drawn with a drawing tube) of transverse sections of bark samples of the taxa studied. Phloem rays are indicated with lines showing their course. Sclerenchyma is shown in black. The number in brackets is the number of the FAA bottle in which the bark sample was fixed and preserved (for vouchers see Table 1). The sclerenchyma elements referred to under each figure are those present in secondary phloem not affected by dilatation growth. Remnants of primary phloem fibres ('pericycle') arrowed. Scale bar = 100 μm

- Tables 1—6 are self-explanatory.

TABLE 1. MATERIAL STUDIED

Taxon	Voucher specimen number	Locality (grid-reference)	FAA Bottle Number	National Tree number	De Dalla Torre & Harms genus number
Acalypha glabrata Thunb. *var. glabrata*	Van Wyk 10183	2428CD	1568	335.1	4407
	Van Wyk 10184	2428CD	1569	335.1	4407
	Van Wyk 10222	2229DD	1607	335.1	4407
Acalypha glabrata var. pilosior (Kuntze) Prain	Van Wyk 10209	2230DC	1592	335.1	4407
Acalypha sonderiana Muell. Arg.	Van Wyk 10373	2930DD	1683	335.2	4407
Andrachne ovalis (Sond.) Muell. Arg.	Scott-Shaw s.n.	2930CB	1651	305	4286
Androstachys johnsonii Prain	Van Wyk 10215	2230DA	1599	327	4345a
	Van Wyk 10216	2230DA	1600	327	4345a
Antidesma venosum E. Mey. *ex* Tul.	Abbott 1490	3030CD	1490	318	4327
	Abbott 4330	3030CD	4330	318	4327
Bridelia cathartica Bertol. f.	Van Wyk 10558	2832AD	1731	322	4345
Bridelia micrantha (Hochst.) Baill.	Van Wyk s.n.	3030CD	1491	324	4345
	Archer 465	2229DD	1545	324	4345
	Van Wyk 10127	3129DA	1493	324	4345
	Van Wyk 10205	2330AB	1588	324	4345
	Van Wyk 10323	3030DA	1799	324	4345
Bridelia mollis Hutch.	Van Wyk 10187	2928CD	1572	324	4345
Cavacoa aurea (Cavaco) J. Léonard	Van Wyk 10357	2931CA	1624	332	4353b
	Van Wyk 10358	2931CA	1624	332	4353b
	Van Wyk 10359	2931CA	1624	332	4353b
	Van Wyk 10360	2931CA	1624	332	4353b
	Van Wyk 10368	2830DC	1695	332	4353b
	Van Wyk 10372	2930DD	1677	332	4353b
Cleistanthus schlecteri (Pax) Hutch.	Van Wyk 10369	2830DC	1686	320	4343

Table 1 continued

Taxon	Voucher specimen number	Locality (grid-reference)	FAA Bottle Number	National Tree number	De Dalla Torre & Harms genus number
Clutia pulchella L.	Van Wyk 10198	2329BB	1582	336.1	4448
Croton gratissimus Burch.	Van Wyk 10181	2428CD	1567	328	4348
Croton megalobotrys Meull. Arg.	Archer 1728 Van Wyk 10208	2329AA 2230DC	1728 1591	329 329	4348 4348
Croton mynhertii Pax	Van Wyk 10223	2229DD	1610	—	4348
Croton pseudopulchellus Pax	Van Wyk 10218	2230DA	1602	329.1	4348
Croton sylvaticus Meull. Arg.	Abbott 4265 Abbott 5328 Van Wyk 10255 Van Wyk 10310 Van Wyk 10324	3130AA 3130AA 3030DA 3030DA 3030DA	4265 1643 1770 1794 1806	330 330 330 330 330	4348 4348 4348 4348 4348
Drypetes arguta (Muell. Arg.) Hutch.	Van Wyk 10258 Van Wyk 10363	3030DA 2931CA	1772 1654	313 313	4309 4309
Drypetes gerrardi Hutch.	Abbott 4251 Van Wyk 10133 Van Wyk 10197	3130AA 3129DA 2329BB	1473 1513 1581	314 314 314	4309 4309 4309
Drypetes natalensis (Harv.) Hutch.	Abbott 5334 Van Wyk 10362 Van Wyk 10367	3130AA 2931CA 2830DC	1649 1654 1692	316 316 316	4309 4309 4309
Erythrococca berberidae Prain	Van Wyk 10371A	2930DD	1676	332.1	4368
Erythrococca menyhartii (Pax) Prain	Van Wyk 10185 Van Wyk 10190 Van Wyk 10191	2428CD 2428CD 2428CD	1570 1574 1576	— — —	4368 4368 4368
Euphorbia cooperi N.E. Br. *ex* Berger	Van Wyk 1563	2329BC	1580	346	4498
Euphorbia espinosa Pax	Van Wyk 10219	2230DA	1603	—	4498

Table 1 continued

Taxon	Voucher specimen number	Locality (grid-reference)	FAA Bottle Number	National Tree number	De Dalla Torre & Harms genus number
Euphorbia ingens E. Mey. *ex* Boiss.	Van Wyk 1561	2528CA	1561	351	4498
Euphorbia tirucalli L.	Van Wyk 1562	2528CA	1562	355	4498
Flueggea virosa (Roxb. *ex* Willd.) Voigt	Van Wyk 10194	2329BC	1578	309	4297
	Van Wyk 10195	2329BC	1626	309	4297
	Van Wyk 10196	2329BC	1579	309	4297
Heywoodia lucens Sim	Abbott 4356	3130AA	1469	306	4291a
	Van Wyk 10092	3129DA	1499	306	4291a
Hyaenanche globosa (Gaertn.) Lamb.	Van Wyk 10341	3118DB	1810	319	4336
	Van Wyk 10342	3118DB	1810	319	4336
	Van Wyk 10343	3118DB	1810	319	4336
	Van Wyk 10344	3118DB	1815	319	4336
	Van Wyk 10345	3118DB	1815	319	4336
Hymenocardia ulmoides Oliv.	Van Wyk 10212	2230DA	1595	317	4325
	Van Wyk 10213	2230DA	1596	317	4325
	Van Wyk 10214	2230DA	1597	317	4325
Lachnostylis bilocularis R.A. Dyer	Van Wyk 12204	3322BC	2213	307.1	4291
	Van Wyk 12205	3322BC	2214	307.1	4291
	Van Wyk 12206	3322BC	2215	307.1	4291
Lachnostylis hirta (L.f.) Muell. Agr.	Van Wyk 12199	3322DC	2154	307	4291
	Van Wyk 12200	3322DC	2155	307	4291
	Van Wyk 12201	3322DC	2156	307	4291
	Van Wyk 12202	3322DC	2157	307	4291
Macaranga capensis (Baill.) Benth. *ex* Sim	Abbott 4275	3130AA	1476	335	4400
	Abbott 5329	3130AA	1638	335	4400
	Van Wyk 10128	3129DA	1492	335	4400
	Van Wyk 10251	3030DA	1769	335	4400
	Van Wyk 10260	3030DA	1771	335	4400
	Van Wyk 10306	3030DA	1812	335	4400

Table 1 continued

Taxon	Voucher specimen number	Locality (grid-reference)	FAA Bottle Number	National Tree number	De Dalla Torre & Harms genus number
Margaritaria discoidea (Baill.) Webster	Abbott 4263	3130AA	4263	310	4299a
	Van Wyk 10217	2230DA	1601	310	4299a
	Van Wyk s.n.	3130AA	1628	310	4299a
Micrococca capensis (Baill.) Prain	Van Wyk 10254	3030DA	1770	332.2	4367
	Van Wyk 10327	3030DA	1805	332.2	4367
	Van Wyk 10336	3030DA	1796	332.2	4367
Phyllanthus cedrifolius Verdoorn	Abbott 4416	3129BC	1421	312	4299
Phyllanthus reticulatus Poir	Van Wyk 10200	2230DA	1584	311	4299
	Van Wyk 10203	2230DC	1587	311	4299
	Van Wyk 10204	2230DC	1587	311	4299
Pseudolachnostylis maprounefolia Pax	Archer 453	2428CD	R1543	308	4295
	Van Wyk 10178	2428CD	1565	308	4295
	Van Wyk 10180	2428CD	1566	308	4295
	Van Wyk 10210	2230DC	1593	308	4295
Sapium ellipticum (Hochst.) Pax	Van Wyk 10050	3129DA	1511	342	4483
	Van Wyk 10250	2430DD	1656	342	4483
	Van Wyk 10298	3030DA	1787	342	4483
Sapium integerrimum (Hochst.) J. Léonard	Van Wyk 10366	2830DC	1691	343	4483
	Van Wyk 10371	28322CA	1682	343	4483
Spirostachys africana Sond.	Van Wyk 10192	2428CD	1577	341	4478
	Van Wyk 10225	2229DD	1612	341	4478
Suregada africana (Sond.) Kuntze	Van Wyk 10364	2931CA	1654	338	4464
Synadenium cupulare (Boiss.) L.C. Wheeler	Van Wyk 1609	2229DD	1609	357.1	4500
Uapaca kirkiana Muell. Arg	Abbott 5322	2032BA	1640	—	4329
	Abbott 5326	2032BA	1641	—	4329
	Abbott 5335	2032BA	1643	—	4329
Uapaca sansibarica Pax	Abbott 5337	2032BA	1639	—	4329
	Abbott 5341	2032BA	1638	—	4329

TABLE 2. SEGREGATE FAMILIES BASED ON GENERA SOMETIMES INCLUDED IN THE EUPHORBIACEAE — AS RECOGNIZED BY SELECTED AUTHORS [Webster (1975, 1987) does not recognize segregate families]

Genus	Airy-Shaw (1965)	Dahlgren (1980)	Takhtajan (1980)	Cronquist (1981)	Radcliffe-Smith (1987)	Meeuse (1990)
*Androstachys**	Androstachydaceae	—	—	—	—	Androstachydaceae
Bischofia	Bischofiaceae	—	Bischofiaceae	—	Bischofiaceae	Bischofiaceae
*Hymenocardia**	Hymenocardiaceae	Hymenocardiaceae	Hymenocardiaceae	Hymenocardiaceae	Hymenocardiaceae	Hymenocardiaceae
Paivaeusa	—	—	—	—	—	Paivaeusaceae
Panda	Pandaceae	—	—	—	—	—
Pera	Peraceae	—	Peraceae	—	Peraceae	Peraceae
*Phyllanthus**	—	—	—	—	—	Phyllanthaceae
Picrodendron	Picrodendraceae	Picrodendraceae	Picrodendraceae	Picrodendraceae	—	—
*Putranjiva, Drypetes**	—	—	—	Putranjivaceae	—	Putranjivaceae
*Stilago, Antidesma**	Stilaginaceae	—	Stilaginaceae	Stilaginaceae	Stilaginaceae	Stilaginaceae
*Uapaca**	Uapacaceae	Uapacaceae	Uapacaceae	Uapacaceae	Uapacaceae	Uapacaceae

*Genera with southern African members

TABLE 3 INFRAFAMILIAL CLASSIFICATION OF THE EUPHORBIACEAE PROPOSED BY HUTCHINSON (1969) [an asterisk denotes genera included in this study.]

TRIBE	SUBTRIBE	GENUS
Glochidieae	Glochidiinae	*Glochidion; Heywoodia** & 4 genera
Caletieae	—	*Pseudanthus* & 2 genera
Wielandieae	—	*Wielandia; Andrachne*; Lachnostylis** & 3 genera
Phyllantheae	Phyllantheae	*Phyllanthus*; Flueggea** & 4 genera
Drypeteae	Drypetinae	*Drypetes** & 3 genera
Hymenocardieae	—	*Hymenocardia** & 5 genera
Antidesmeae	Antidesminae	*Antidesma*; Pseudolachnostylis** & 7 genera
Hyaenancheae	Toxicodendrinae	*Hyaenanche*; Androstachys** & 4 genera
Porantheraeae	—	*Poranthera* & 1 genus
Uapaceae	—	*Uapaca**
Bishoffieae	—	*Bischoffia* & 4 genera
Bridelieae	—	*Bridelia*; Cleistanthus** & 1 genus
Codiaeae	Codiaeinae	*Codiaeum* & 6 genera
Clutieae	—	*Clutia** & 4 genera
Ricinocarpeae	—	*Ricinocarpus* & 3 genera
Chrozophoreae	—	*Chrozophora* & 11 genera
Ricinodendreae	Ricinodendrinae	*Ricinodendron* & 3 genera
Jatropheae	Jatropheae	*Jatropha* & 4 genera
Gelonieae	—	*Suregada** & 14 genera
Manihoteae	—	*Manihot*
Mareyeae	—	*Mareya* & 10 genera

Table 3 continued

TRIBE	SUBTRIBE	GENUS
Neoboutonieae	—	*Neoboutonia* & 2 genera
Claoxyleae	—	*Claoxylon; Erythrococca*; Micrococca** & 2 genera
Malloteae	—	*Mallotus* & 13 genera
Cephalocrotoneae	—	*Cephalocroton* & 6 genera
Alchornieae	—	*Alchornea* & 7 genera
Mercurialideae	—	*Mercutialis* & 3 genera
Pachystromateae	—	*Pachystroma*
Acalypheae	Acalyphinae	*Acalypha**
Pycnocomeae	—	*Pycnocoma* & 7 genera
Plukenetieae	Plukenetiinae	*Plukenetia* & 12 genera
Macarangeae	Endosperminae	*Macaranga** & 7 genera
Hippomaneae	—	*Hippomane* & 3 genera
Hureae	Hurinae	*Hura* & 1 genus
Dalechampieae	—	*Dalechampia*
Pereae	—	*Pera*
Ricineae	Ricininae	*Ricinus* & 3 genera
Crotoneae	Eucrotoneae	*Croton** & 4 genera
Joannesieae	Joannesieae	*Joannesia* & 2 genera
Euphorbieae	—	*Euphorbia*; Synadenium** & 9 genera

TABLE 4. INFRAFAMILIAL CLASSIFICATION OF THE EUPHORBIACEAE ACCORDING TO WEBSTER (1975, 1987)

SUBFAMILY	TRIBE	SUBTRIBE	GENUS
Phyllanthoideae	Wielandieae	—	*Wielandia, Heywoodia**, *Lachnostylis** & 7 genera
	Amanoeae (Phyllantheae)	Amanoinae	*Amanoa* & 1 genus
	Bridelieae	—	*Bridelia**, *Cleistanthus**
	Dicoelieae	—	*Dicoelia*
	Porantheroideae (Caletieae)	Poranthereae	*Poranthera, Andrachne** & 1 genus
	Spondiatheae	—	*Spondianthus*
	Antidesmeae	—	*Antidesma** & 4 genera
	Aporuseae	—	*Aporusa* & 6 genera
	Drypeteae	—	*Drypetes**, *Putranjiva*† & 1 genus
	Phyllantheae ('Phylantheae')	Securineginae	*Securinega, Pseudolachnostylis** & 7 genera
		Flueggeinae	*Fleuggea**, *Margaritaria**, *Phyllanthus** & 6 genera
	Hymenocardieae	Hymenocardieae	*Hymenocardia**†
	Uapaceae	Uapaceae	*Uapaca**†
	Bischofieae	Bischoffieae	*Bischofia*†
Oldfieldioideae	Hyaenancheae	Mischodontinae	*Mischodon* & 4 genera
		Hyaenanchinae	*Hyaenanche**
		Paivaeusinae	*Paivaeusa*† (= *Oldfieldia*) & 3 genera
		Dissiliariinae	*Dissiliaria* & 3 genera
	Petalostigmateae	Petalostigmatinae	*Petalostigma, Androstachys**†
	Caletieae	—	*Caletia (= Micrantheum)* & 3 genera
	Pierodendreae (Picrodendronaceae)	—	*Picrodendron*†

Table 4 continued

SUBFAMILY	TRIBE	SUBTRIBE	GENUS
Acalyphoideae	Clutieae ('Cluytieae')	Cluytieae	*Clutia**
	Pogonophoreae (Hippomaneae)	Pogonophoreae	*Pogonophora*
	Chaetocarpeae (Hippomaneae)	Chaetocarpeae	*Chaetocarpus* & 1 genus
	Cheiloseae (Hippomaneae)	Cheiloseae	*Cheilosa* & 1 genus
	Erismantheae	—	*Erismanthus* & 2 genera
	Ampereae	—	*Ampera* & 1 genus
	Chrozophoreae	Speranskiinae	*Speranskia*
		Ditaxinae ('Ditaxideae')	*Ditaxis* & 3 genera
		Doryxylinae	*Dorxylon* & 3 genera
		Chrozophorinae ('Chrozophoreae')	*Chrozophora*
	Agrostistachydeae (Acalypheae)	—	*Agrostistachys* & 2 genera
Acalyphoideae	Caryodendreae	—	*Caryodendron* & 2 genera
	Pycnocomeae	Pycnocominae	*Pycnocoma*, *Argomuellera* & 1 genera
		Blumeodendrinae	*Blumeodendron* & 2 genera
	Bernardieae (Acalypheae)	Mercurialinae ser. Bernardiiformes	*Bernardia*, *Neupalissya* & 2 genera
	Epiprineae	Epiprininae ('Epiprineae')	*Epiprinus*, *Cephalocroton* & 4 genera
		Cephalomappinae	*Cephalomappa*
	Adelieae	—	*Adelia* & 3 genera
	Alchornieae	Alchorneinae	*Alchornea* & 4 genera
		Conceveibinae	*Conceveiba* & 2 genera
	Acalypheae	Ricininae ('Ricineae')	*Ricinus*
		Adrianinae ('Adrianeae')	*Adriana*
		Lasiococcinae	*Lasiococca* & 2 genera
		Mercurialinae (Mercurialideae)	*Mercurialis* & 2 genera

Table 4 continued

SUBFAMILY	TRIBE	SUBTRIBE	GENUS
Acalyphoideae	Acalypheae (cont.)	Dysopsidinae	*Dysopsis*
		Macaranginae	*Macaranga**
		Cleidiinae	*Cleidion* & 3 genera
		Claoxylinae (Claoxyleae, Mareyeae)	*Claoxylon*, *Erythrococca**, *Micrococca** & 6 genera
		Acalyphinae (Acalypheae)	*Acalypha**
		Rottlerinae ('Rottlereae', Malloteae)	*Rottlera*, *Mallotus* & 6 genera
	Plukenetieae	Plukenetiinae ('Plukenetieae')	*Plukenetia*, *Pterococcus* & 6 genera
		Tragiinae	*Tragia* & 5 genera
	Dalechampieae	—	*Dalechampia*
	Omphaleae (Hippomaneae)	Omphaleinae	*Omphalea*
	Pereae (Peraceae)	—	*Pera*†
Crotonoideae	Micrandreae	Micrandrinae (Micrandreae)	*Micrandra* & 2 genera
		Heveinea ('Heveeae')	*Hevea*
	Manihoteae (Hippomaneae)	Manihoteae	*Manihot* & 3 genera
	Adenoclineae	Adenoclininae ('Adenoclineae)	*Adenocline* & 4 genera
		Endosperminae	*Endospermum*
	Gelonieae (Hippomaneae)	Gelonieae	*Gelonium (= Suregada*)*
	Elateriospermeae	—	*Elateriospermum*
	Joanneseiae	Jatrophiinae (Jatropheae)	*Jatropha* & 3 genera
		Ricinodendrinae (Ricinodendreae)	*Ricinodendron* & 1 genus
		Joannesiinae ('Johanneseae')	*Joannesia* & 3 genera
	Codiaeae (Cluytieae)	Codiaeinae	*Codiaeum* & 18 genera

Table 4 continued

SUBFAMILY	TRIBE	SUBTRIBE	GENUS
Crotonoideae	Ricinocarpeae	Ricinocarpinae (Ricinocarpeae Euricinocarpeae)	*Ricinocarpus* & 2 genera
		Bertyinae ('Bertyeae')	*Bertya* & 2 genera
	Trigonostemoneae	—	*Trigonostemon* & 2 genera
	Aleuritideae	Aleuritinae (Aleuritideae)	*Aleurites* & 2 genera
		Grosserinae	*Grossera, Cavacoa** *Tannodia*
		Crotonogyninae	*Crotonogyne* & 2 genera
		Garciinae (Garcieae)	*Garcia*
		Neoboutoninae (Neoboutonieae)	*Neoboutonia* & 1 genus
	Crotoneae (Crotonieae)	—	*Croton** & 2 genera
Euphorbioideae	Stomatocalyceae (Stomatocalycinae)	Stomatocalycinae	*Stomatocalyx* & 1 genus
		Hamilcoinae	*Hamilcoa* & 1 genus
	Hippomaneae	Mabeinae	*Mabea* & 2 genera
		Carumbiinae ('Carumbieae')	*Carumbium*
		Hippomaninae ('Hippomaneae')	*Hippomane, Sapium*, Spirostachys*, Excoecaria, Maprounea* & 11 genera
	Pachystromateae (Acalypheae)	Pachystromatinae	*Pachystroma*
	Hureae ('Huraceae')	—	*Hura* & 3 genera
	Euphorbieae	Anthosteminae (Anthostemeae)	*Anthostema* & 1 genus
		Neoguillauminiinae	*Neoguillauminia* & 1 genus
		Euphorbiinae	*Euphorbia*, Synadenium** & 4 genera

Footnote: * indicates genera studied; † denotes type genera of segregate families mentioned in Table 2; the first genus listed is the type genus.

TABLE 5. CLASSIFICATION OF SOUTHERN AFRICAN EUPHORBIACEAE ACCORDING TO WEBSTER (1975, 1987)
[Key: * = genera studied; # = shrubs; + = herbs; woody genera underlined; ● naturalised genera]

SUBFAMILY	TRIBE	SUBTRIBE	GENUS
Phyllanthoideae	Wielandieae		*Heywoodia**, *Lachnostylis**#
	Bridelieae		*Bridelia**#, *Cleistanthus**#
	Porantthereae		*Andrachne**#+
	Antidesmeae		*Antidesma**
	Drypeteae		*Drypetes**#
	Phyllantheae	Securineginae	*Pseudolachnostylis**#
		Flueggeinae	*Fleuggea**#, *Margaritaria**#, *Phyllanthus**#+
	Hymenocardieae	Hymenocardieae	*Hymenocardia**#
	Uapaceae	Uapaceae	*Uapaca**
Oldfieldioideae	Hyaenancheae	Hyaenanchinae	*Hyaenanche**#
	Petalostigmateae	Petalostigmatinae	*Androstachys**
Acalyphoideae	Clutieae		*Clutia**#
	Chrozophoreae	Ditaxinae	*Caperonia*+
		Chrozophorinae	*Chrozophora*+
	Pycnocomeae	Pycnocominae	*Argomuellera*#
	Bernardieae		*Neopalissya*
	Epiprineae	Epiprininae	*Cephalocroton*#
	Alchornieae	Alchorneinae	*Alchornea*#
	Acalypheae	Ricininae	●*Ricinus*#+
		Mercurialinae	●*Mercurialis*+, *Leidesia*+, *Seidelia*+
		Macaranginae	*Macaranga**#
		Claoxylinae	*Erythrococca**#, *Micrococca**#+
		Acalyphinae	*Acalypha**#+
		Rottlerinae	*Mallotus*#

Table 5 continued

SUBFAMILY	TRIBE	SUBTRIBE	GENUS
Acalyphoideae	Plukenetieae	Plukenetiinae	*Pterococcus*#+
		Tragiinae	*Tragia*+, *Sphaerostylis*+
	Dalechampieae		*Dalechampia*#+
Crotonoideae	Manihoteae	Manihoteae	●*Manihot*#
	Adenoclineae	Adenoclininae	*Adenocline*+
	Gelonieae	Gelonieae	*Suregada**#
	Joanneseiae	Jatrophiinae	*Jatropha*#+
		Ricinodendrinae	*Ricinodendron*
	Aleuritideae	Aleuritinae	●*Aleurites*
		Grosserinae	*Cavacoa**
		Neoboutoninae (Neoboutonieae)	*Neoboutonia*
	Crotoneae (Crotonieae)		*Croton**#+, ●*Eremocarpus*+
Euphorbioideae	Hippomaneae		●*Holomanthus*#
		Hippomaninae	*Excoecaria*#, *Maprounea*#, *Sapium**, *Spirostachys**
	Euphorbieae	Euphorbiinae	*Euphorbia**#+, *Monadenium*#+, *Synadenium**#

TABLE 6: SUMMARY OF SELECTED BARK ANATOMICAL CHARACTERS

Key: + = present; — = absent; ++ = abundant;
± = sparse/poorly developed; +(r) = crystalliferous strands randomly dispersed; +(s) = crystalliferous strands associated with sclerenchyma; n+ = not observed

	Dilatation tissue	Sclerenchyma	Predominant sclerenchyma type[1]			Calcium oxalate crystals	Predominant crystal type			Axial chambered crystalliferous strands	Phellem with lignified cells	Phelloderm	Cortex
			Fibres	Sclereids	Fibre-sclereids		Prisms	Druses	Styloids				
Subfamily: Phyllanthoideae Tribe: Wielandieae Genus: *Heywoodia* species: *lucens*	+	+	—	+	—	+	+	+	—	—	—	+	—
Genus: *Lachnostylis* species: *bilocularis*	—	+	++	+	+	+	+	+	—	+(s)	—	—	—
species: *hirta*	+	+	+	+	±	+	+	+	—	+(r)	—	+	+
Tribe: Bridelieae Genus: *Bridelia* species: *cathartica*	—	+	+	—	—	+	++	+	—	+(s)	—	—	—
species: *micrantha*	+	+	+	±	—	+	++	+	—	+(s)	+	+	—
species: *mollis*	—	+	+	—	—	+	+	—	—	+(s)	—	—	—
Genus: *Cleistanthus* species: *schlecteri*	—	+	+	—	±	+	+	+	—	—	+	—	—
Tribe: Porantheree Subtribe: Porantheree Genus: *Andrachne* species: *ovalis*	+	+	—	+	+	—	—	—	—	—	—	—	—
Subtribe: Antidesmeae Genus: *Antidesma* species: *venosum*	—	+	++	+	+	+	++	+	—	—	—	—	—
Tribe: Drypeteae Genus: *Drypetes* species: *arguta*	+	+	—	++	±	+	+	—	—	+(r)	+	+	+
species: *gerrardi*	+	+	+	+	+	+	++	++	—	+(r)/(s)	+	+	+
species: *natalensis*	+	+	+	+	—	+	+	—	—	+(r)/(s)	+	+	+

Key: + = present; — = absent; ++ = abundant;
± = sparse/poorly developed; +(r) = crystalliferous strands randomly dispersed; +(s) = crystalliferous strands associated with sclerenchyma; n+ = not observed

	Dilatation tissue	Sclerenchyma	Predominant sclerenchyma type[1]			Calcium oxalate crystals	Predominant crystal type			Axial chambered crystalliferous strands	Phellem with lignified cells	Phelloderm	Cortex
			Fibres	Sclereids	Fibre-sclereids		Prisms	Druses	Styloids				
Tribe: Phyllantheae Subtribe: Securineginae Genus: *Pseudolachnostylis* species: *maprounefolia*	+	+	—	++	+	+	++	+	—	+(r)	+	+	+
Subtribe: Flueggeinae Genus: *Flueggea* species: *virosa*	+	+	++	+	—	+	+	+	—	+(s)	+	—	—
Genus: *Margaritaria* species: *discodea*	+	+	—	+	++	+	++	+	—	+(s)	+	+	—
Genus: *Phyllanthus* species: *cedrifolius*	—	+	—	+	+	+	+	—	—	—	—	+	+
species: *reticulatus*	+	+	—	+	—	+	+	—	—	—	—	+	+
Tribe: Hymenocardieae Subtribe: Hymenocardieae Genus: *Hymenocardia* species: *ulmoides*	—	+	—	+	+	+	+	—	—	+(r)/(s)	+	+	—
Tribe: Uapaceae Subtribe: Uapaceae Genus: *Uapaca* species:	±	+	—	+	+	—	—	—	—	n+	+	+	—
Subfamily: Oldfieldioideae Tribe: Hyaenancheae Subtribe: Hyaenanchinae Genus: *Hyaenanche* species: *globosa*	+	+	+	—	±	+	+	—	—	+(r)/(s)	+	+	—
Tribe: Petalostigmateae Subtribe: Petalostigmatinae Genus: *Androstachys* species: *johnsonii*	±	+	++	+	—	+	+	—	—	+(s)	—	—	—

Key: + = present; — = absent; ++ = abundant;
± = sparse/poorly developed; +(r) = crystalliferous strands randomly dispersed; +(s) = crystalliferous strands associated with sclerenchyma; n+ = not observed

	Dilatation tissue	Sclerenchyma	Predominant sclerenchyma type[1]			Calcium oxalate crystals	Predominant crystal type			Axial chambered crystalliferous strands	Phellem with lignified cells	Phelloderm	Cortex
			Fibres	Sclereids	Fibre-sclereids		Prisms	Druses	Styloids				
Subfamily: Acalyphoideae Tribe: Clutieae Subtribe: Cluytieae Genus: *Clutia* species: *pulchella*	+	—	—	—	—	—	—	—	—	—	+	±	—
Tribe: Acalypheae Subtribe: Macaranginae Genus: *Macaranga* species: *capensis*	+	+	++	+	+	+	+	++	—	+(s)	—	+	—
Subtribe: Claoxylinae Genus: *Erythrococca* species: *berberidae*	+	—	—	—	—	+	—	—	+	—	±	+	—
species: *menyhartii*	+	+	+	++	+	+	+	—	++	—	—	±	+
Genus: *Micrococca* species: *capensis*	+	—	—	—	—	+	+	—	++	—	+	+	+
Subtribe: Acalyphinae Genus: *Acalypha* species: *glabrata* variety: *glabrata*	+	+	—	+	—	+	+	—	++	—	—	+	+
variety: *pilosior*	+	—	—	—	—	+	—	+	—	+(r)	+	±	+
species: *sonderiana*	+	+	—	++	+	+	+	++	—	+(s)	+	+	+
Subfamily: Crotonoideae Tribe: Gelonieae Subtribe: Gelonieae Genus: *Suregada* species: *africana*	+	—	—	—	—	+	+	+	—	—	+	±	—
Tribe: Aleuritideae Subtribe: Grosserinae Genus: *Cavacoa* species: *aurea*	+	+	—	+	—	+	+	++	—	+(r)	+	±	—

Key: + = present; — = absent; ++ = abundant;
± = sparse/poorly developed; +(r) = crystalliferous strands randomly dispersed; +(s) = crystalliferous strands associated with sclerenchyma; n+ = not observed

	Dilatation tissue	Sclerenchyma	Predominant sclerenchyma type[1]			Calcium oxalate crystals	Predominant crystal type			Axial chambered crystalliferous strands	Phellem with lignified cells	Phelloderm	Cortex
			Fibres	Sclereids	Fibre-sclereids		Prisms	Druses	Styloids				
Tribe: Crotoneae Genus: *Croton* species: *gratissimus*	+	+	+	+	—	+	+	+	—	+(s)	+	+	—
species: *megalobotrys*	+	+	++	+	—	+	+	+	—	+(s)	—	+	—
species: *menyhartii*	+	+	+	+	—	+	+	+	—	+(s)	±	+	—
species: *pseudopulchellus*	+	+	++	+	—	+	+	+	—	+(s)	+	+	—
species: *sylvaticus*	+	+	++	+	—	+	+	+	—	—	+	±	+
Subfamily: Euphorbioideae Tribe: Hippomaneae Subtribe: Hippomaninae Genus: *Sapium* species: *ellipticum*	+	+	+	+	—	+	+	—	—	—	—	±	—
species: *integerrimum*	+	+	+	+	—	+	+	—	—	—	—	±	—
Genus: *Spirostachys* species: *africana*	+	+	+	—	—	+	+	—	—	—	—	±	—
Tribe: Euphorbieae Subtribe: Euphorbiinae Genus: *Euphorbia* species: *cooperi*	+	—	—	—	—	—	—	—	—	—	—	—	—
species: *espinosa*	+	—	—	—	—	—	—	—	—	—	—	±	+
species: *ingens*	+	—	—	—	—	—	—	—	—	—	—	—	+
species: *tirucalli*	+	+	+	—	—	+	+	—	—	—	—	—	n+
Genus: *Synadenium* species: *cupulare*	+	—	—	—	—	+	+	—	—	—	—	+	+

[1]Refers to sclerenchyma not affected by dilatation growth (excluding secondarily formed sclereids)

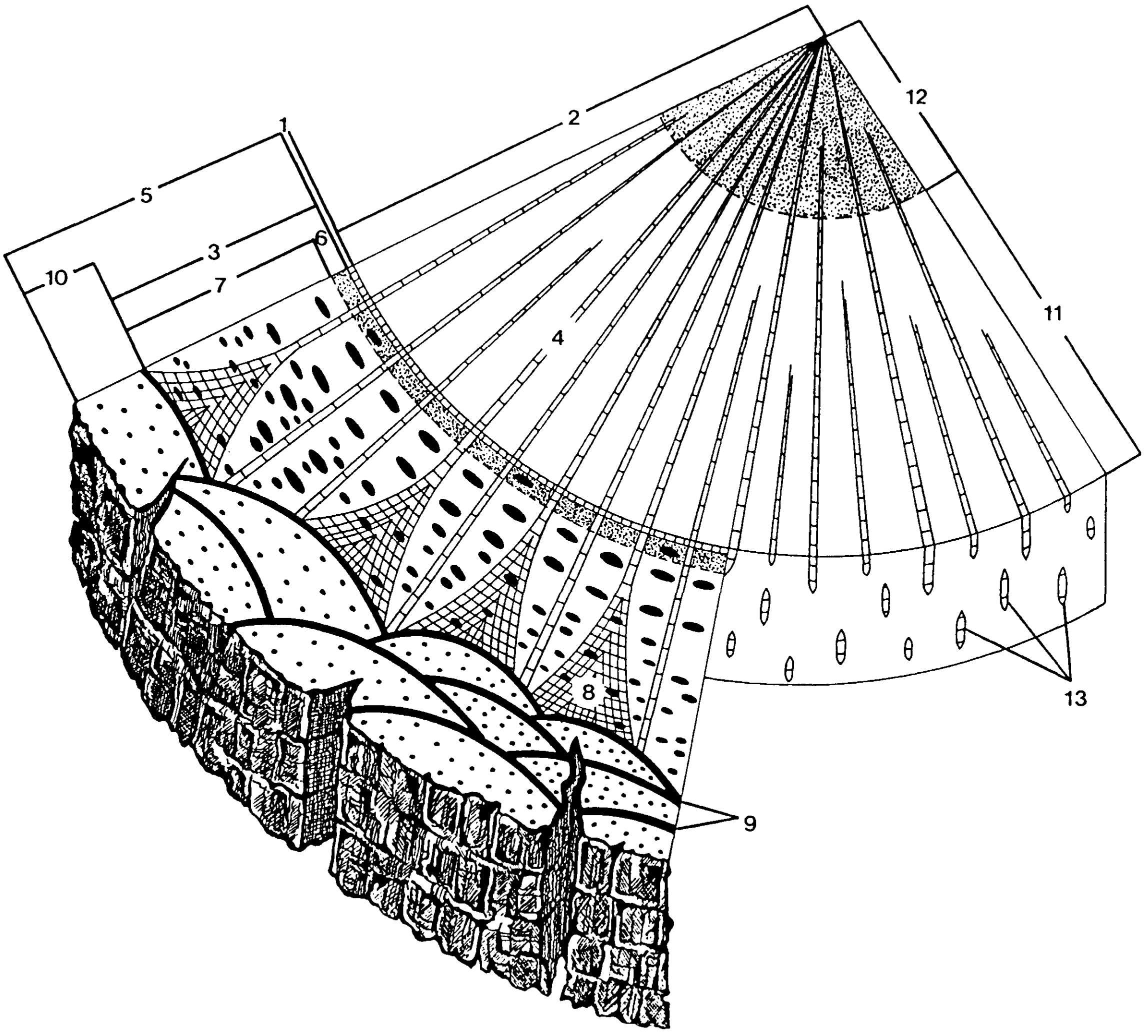

Figure 1. Schematic diagram of a portion of a partly debarked tree trunk showing the position of tissues in the mature bark and associated parts.

1. Vascular cambium
2. Secondary xylem (wood)
3. Secondary phloem
4. Vascular ray (phloem & xylem)
5. Bark
6. Conducting (non-collapsed) phloem
7. Non-conducting (collapsed) phloem
8. Dilatation (expansion) tissue
9. Periderm
10. Rhytidome
11. Sapwood (alburnum)
12. Heartwood (duramen)
13. Xylem rays (exposed ends)

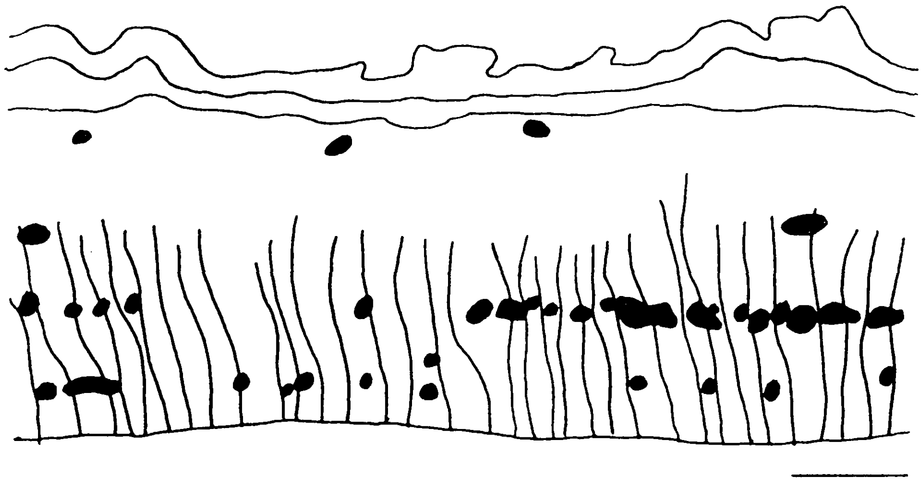

Figure 2. *Acalypha glabrata* var. *glabrata (1607).* Sclerenchyma comprising sclereids.

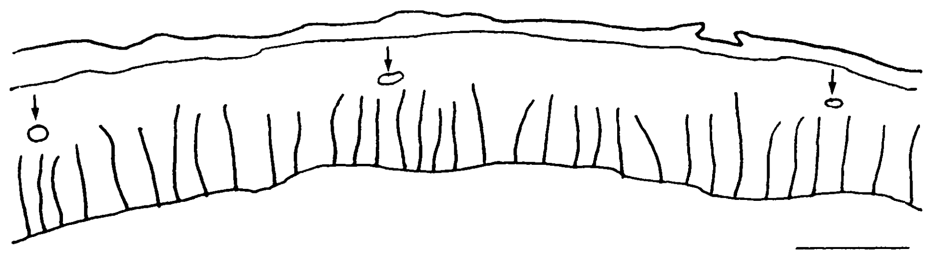

Figure 3. *Acalypha glabrata* var. *pilosior (1592).* Sclerenchyma absent.

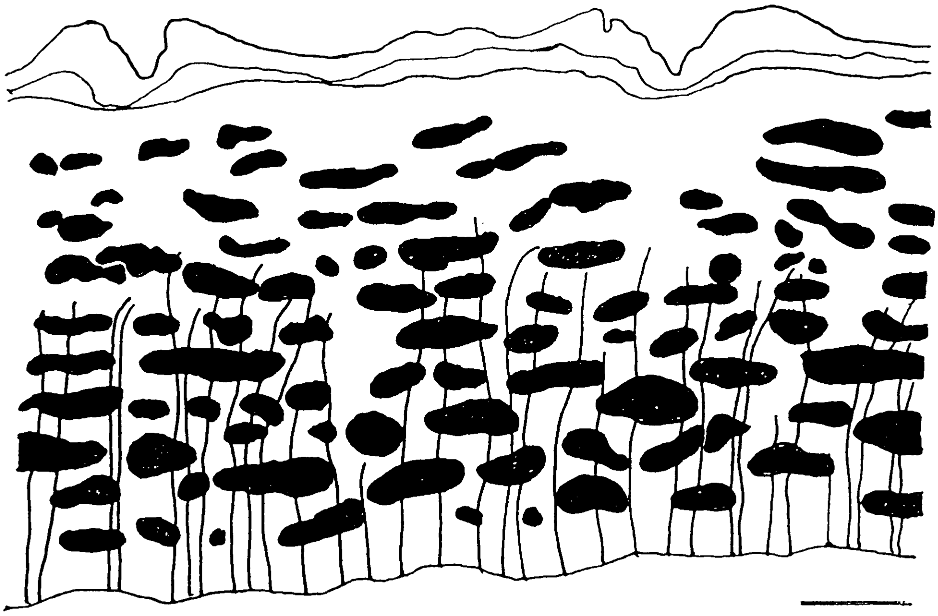

Figure 4. *Acalypha sonderiana (1683)*. Sclerenchyma comprising sclereids and fibre-sclereids.

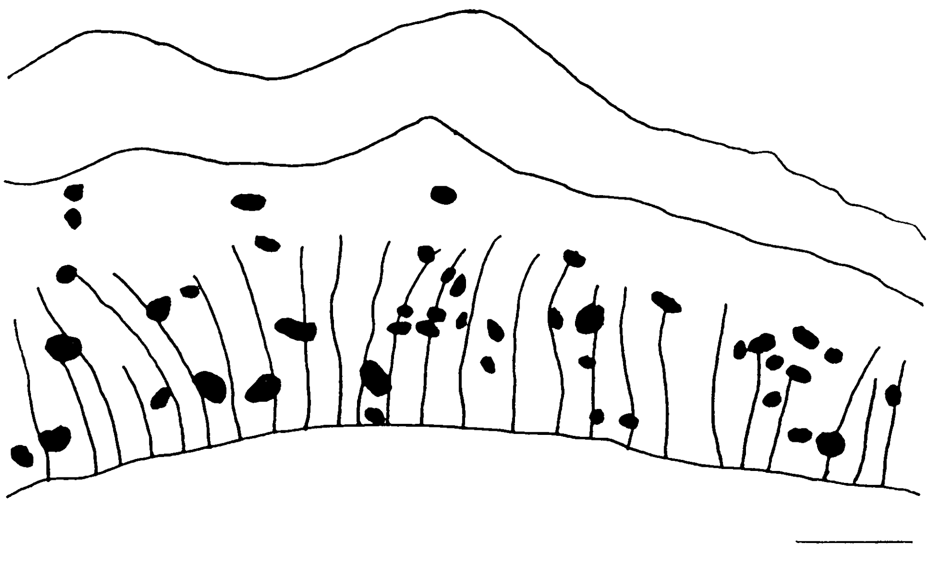

Figure 5. *Andrachne ovalis (1651)*. Sclerenchyma comprising sclereids and fibre-sclereids.

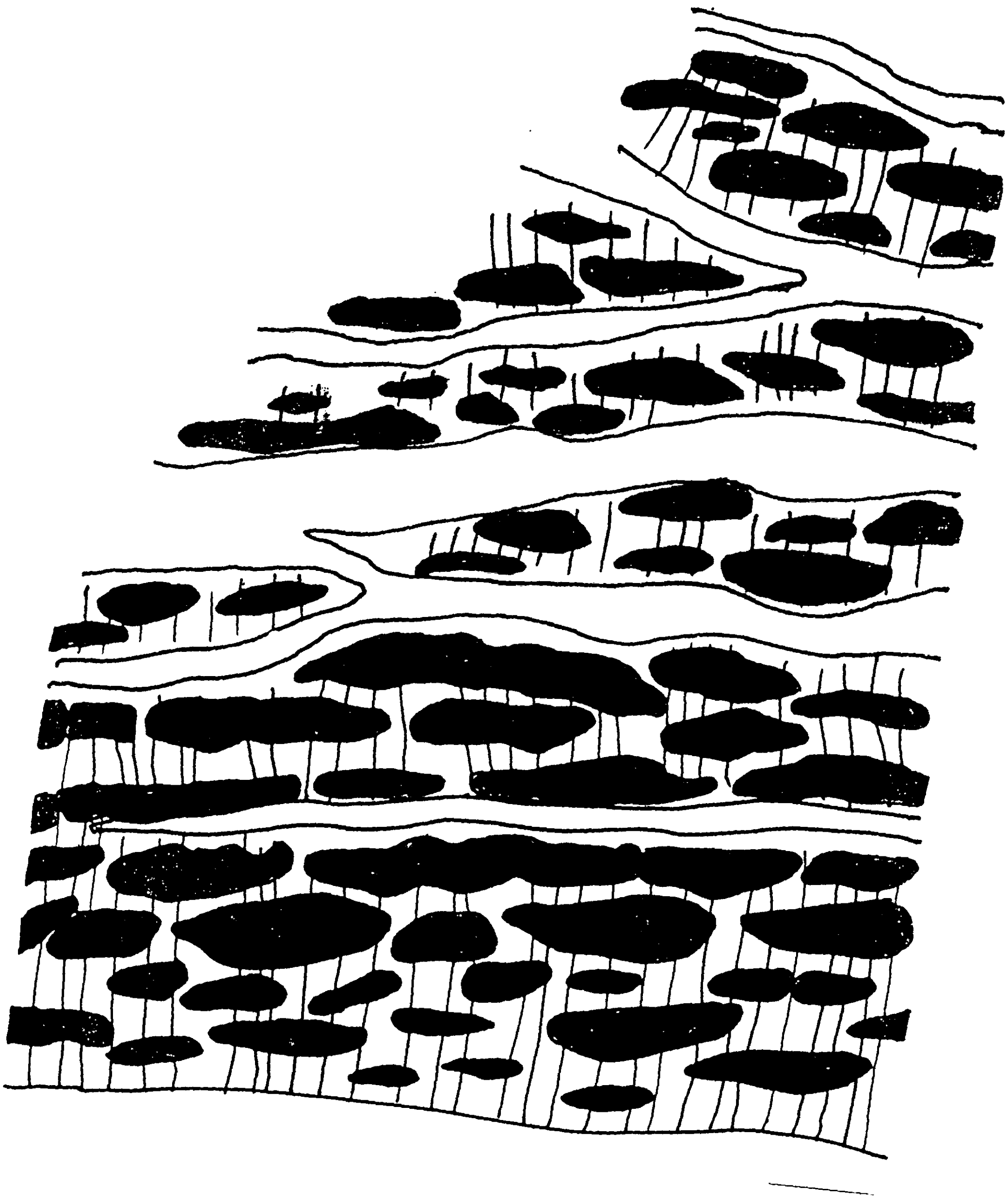

Figure 6. *Androstachys johnsonii (1599)*. Sclerenchyma comprising fibres and sclereids.

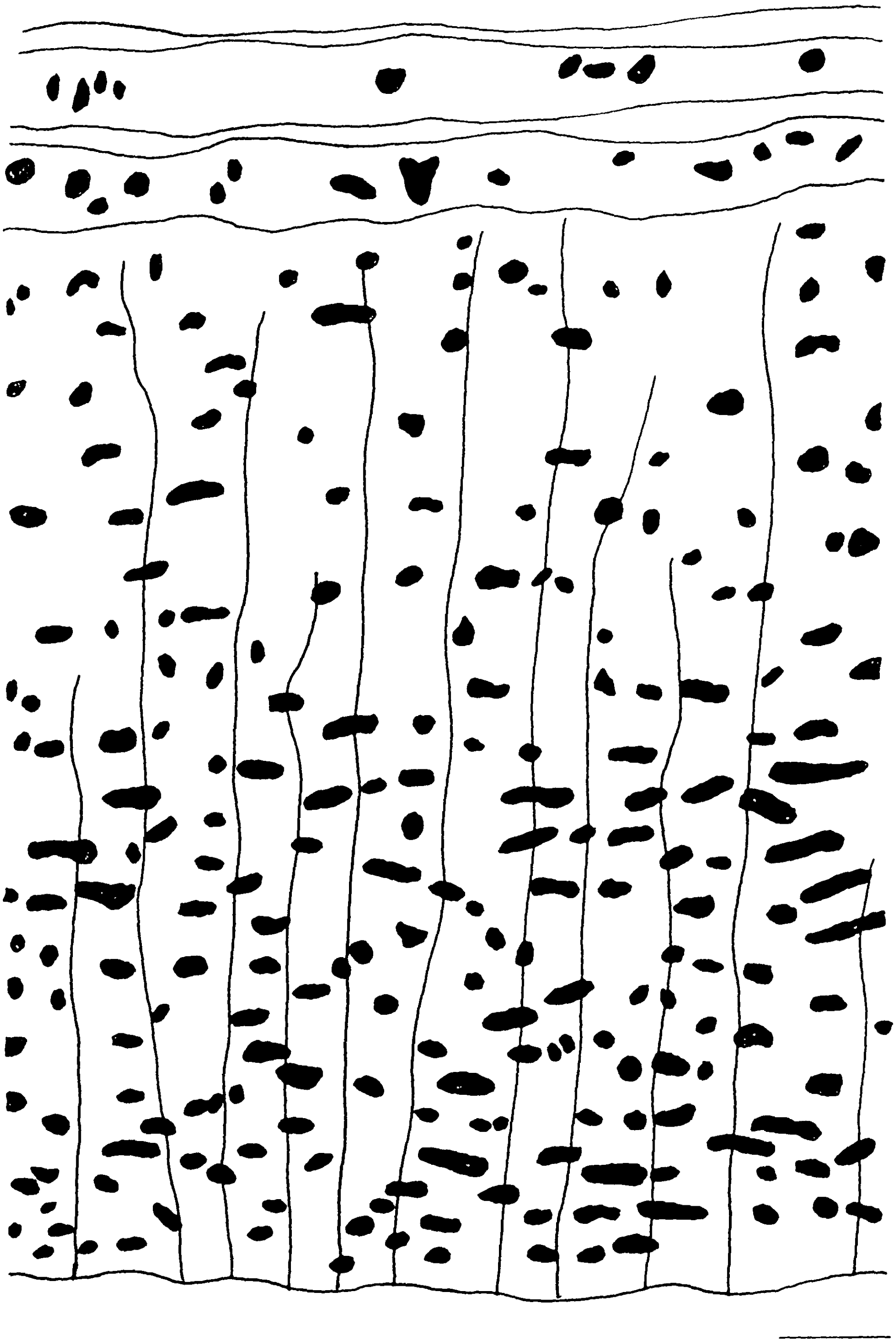

Figure 7. *Antidesma venosum (1490).* Sclerenchyma comprising fibres, sclereids and fibre-sclereids.

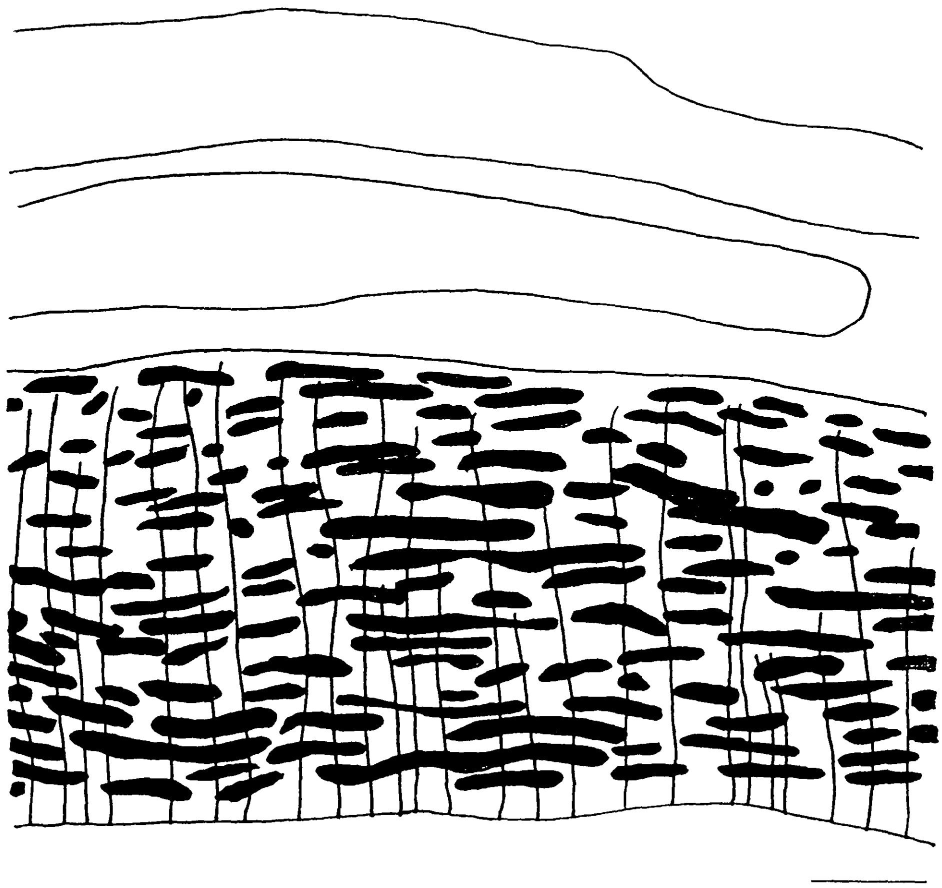

Figure 8. *Bridelia cathartica (1731)*. Sclerenchyma comprising lignified and gelatinous fibres.

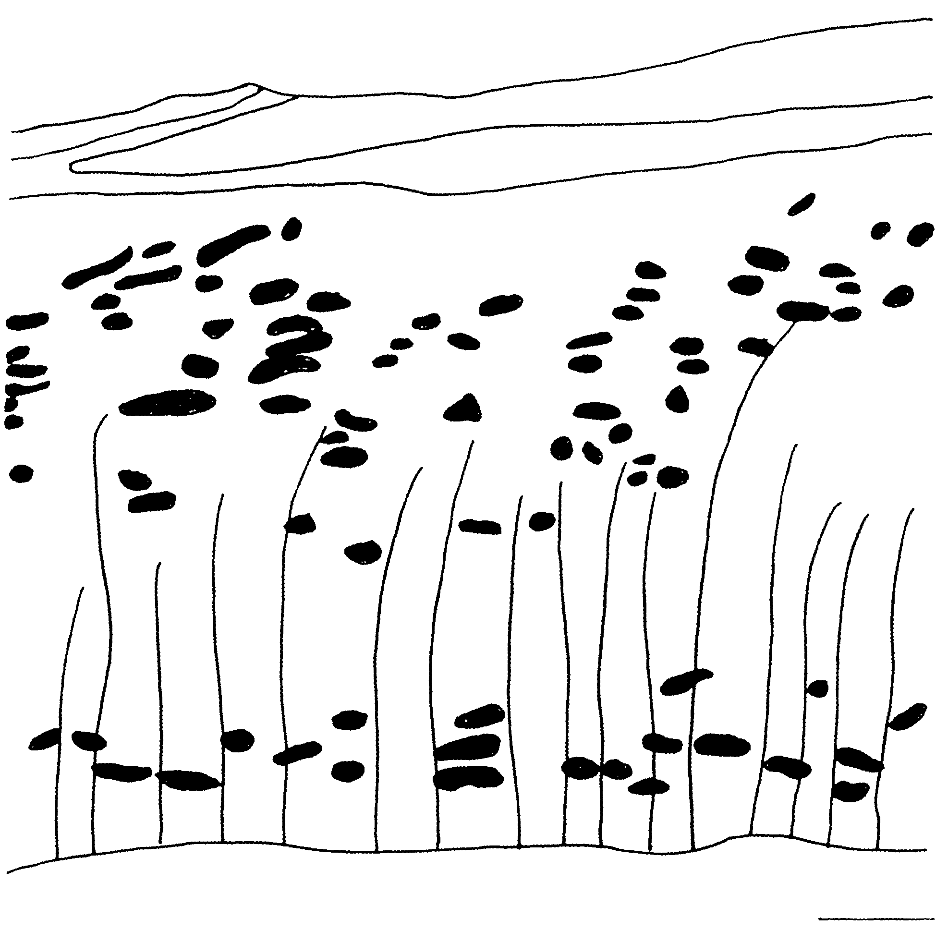

Figure 9. *Bridelia micrantha (1493).* Sclerenchyma comprising lignified fibres, gelatinous fibres and sclereids.

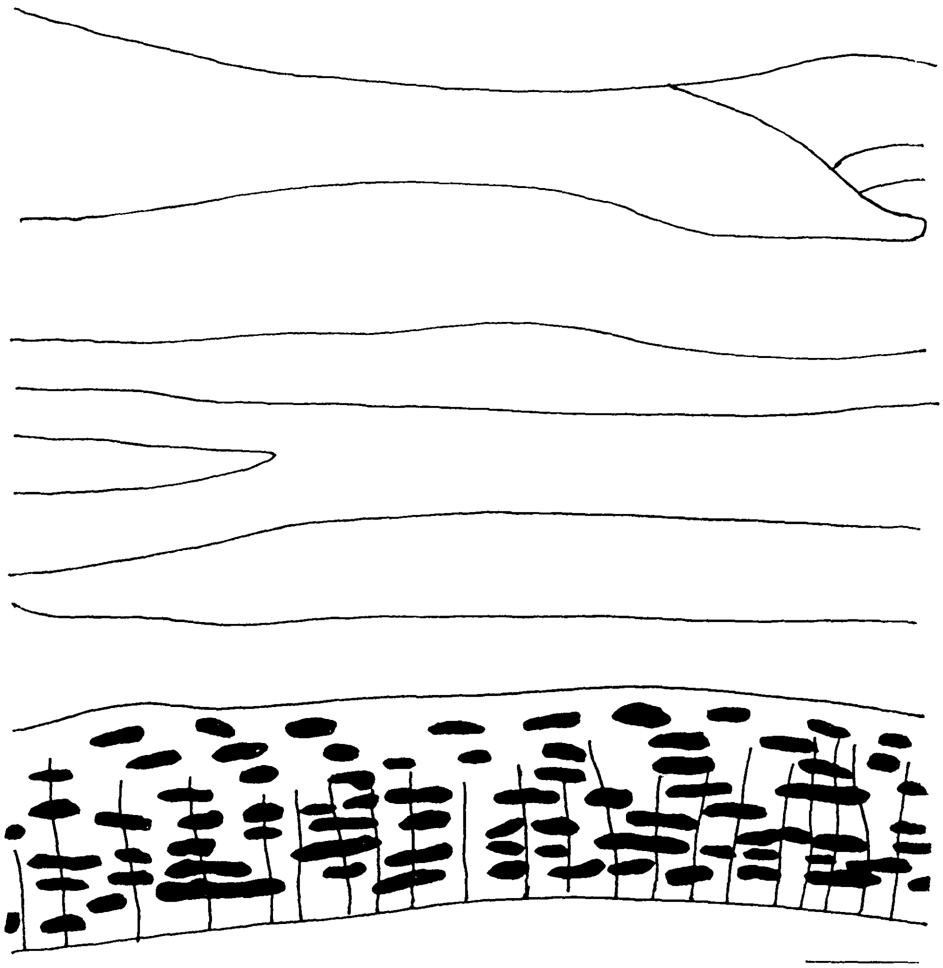

Figure 10. *Bridelia mollis (1572).* Sclerenchyma comprising lignified and gelatinous fibres.

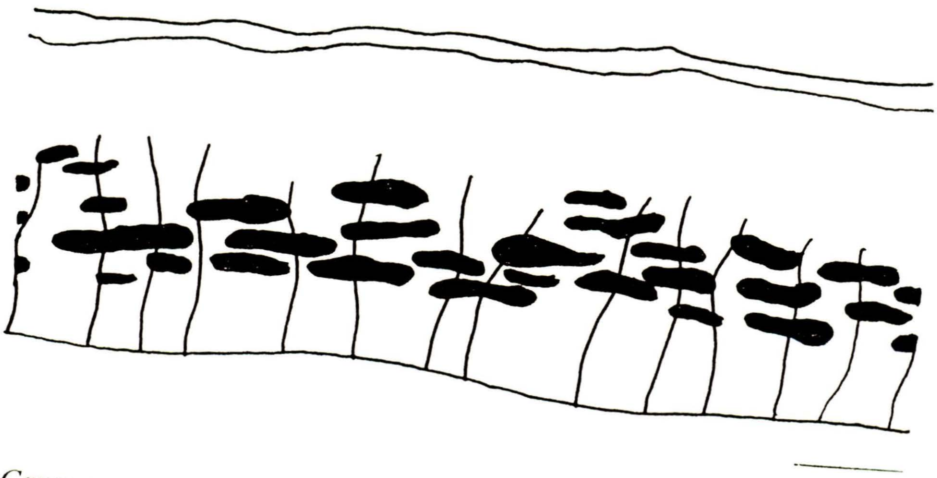

Figure 11. *Cavacoa aurea (1695)*. Sclerenchyma comprising sclereids.

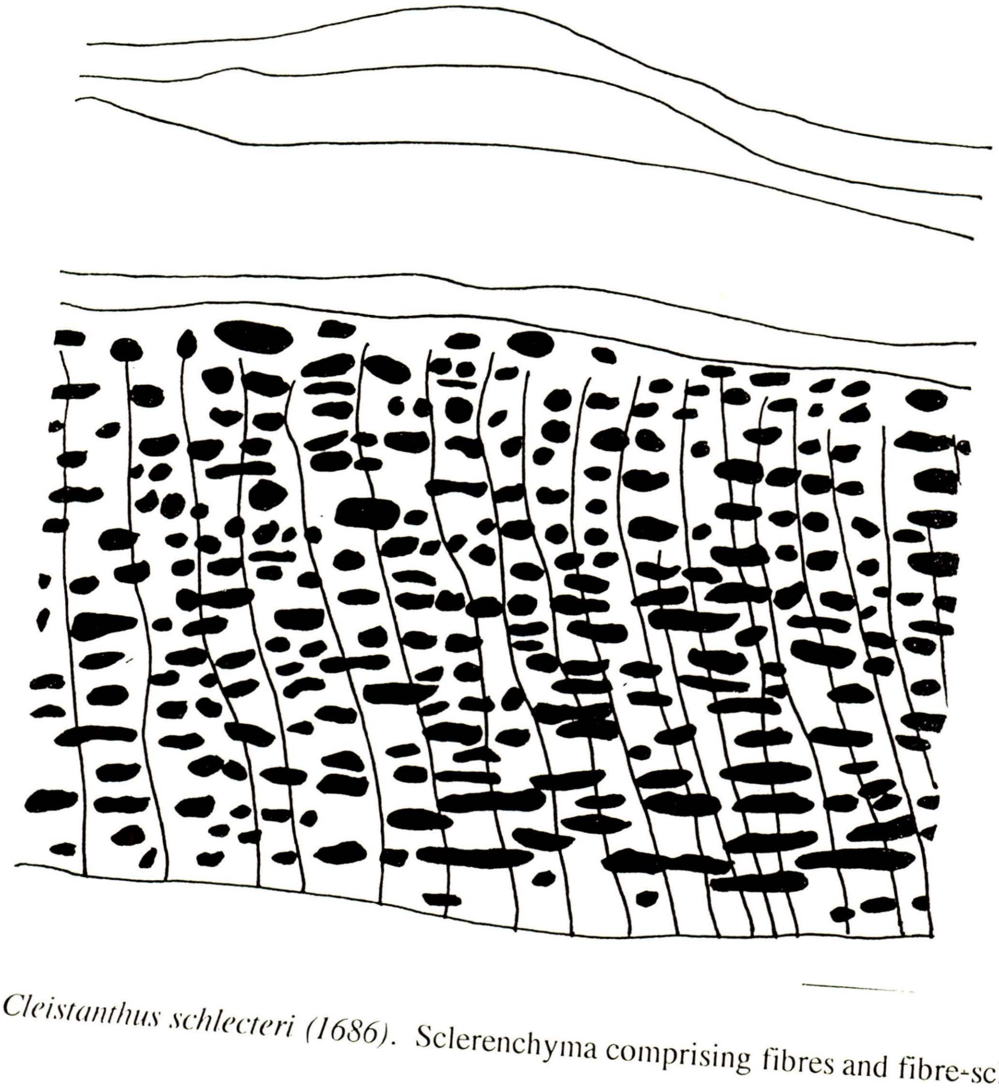

Figure 12. *Cleistanthus schlecteri (1686)*. Sclerenchyma comprising fibres and fibre-sclereids.

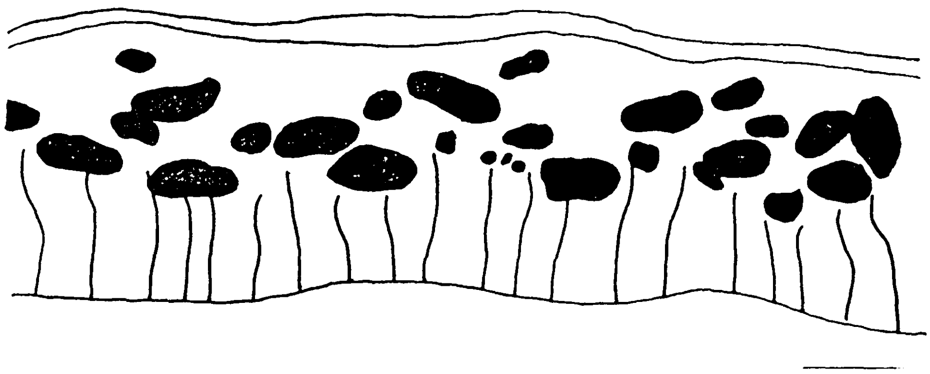

Figure 13. *Clutia pulchella (1582).* Sclerenchyma absent.

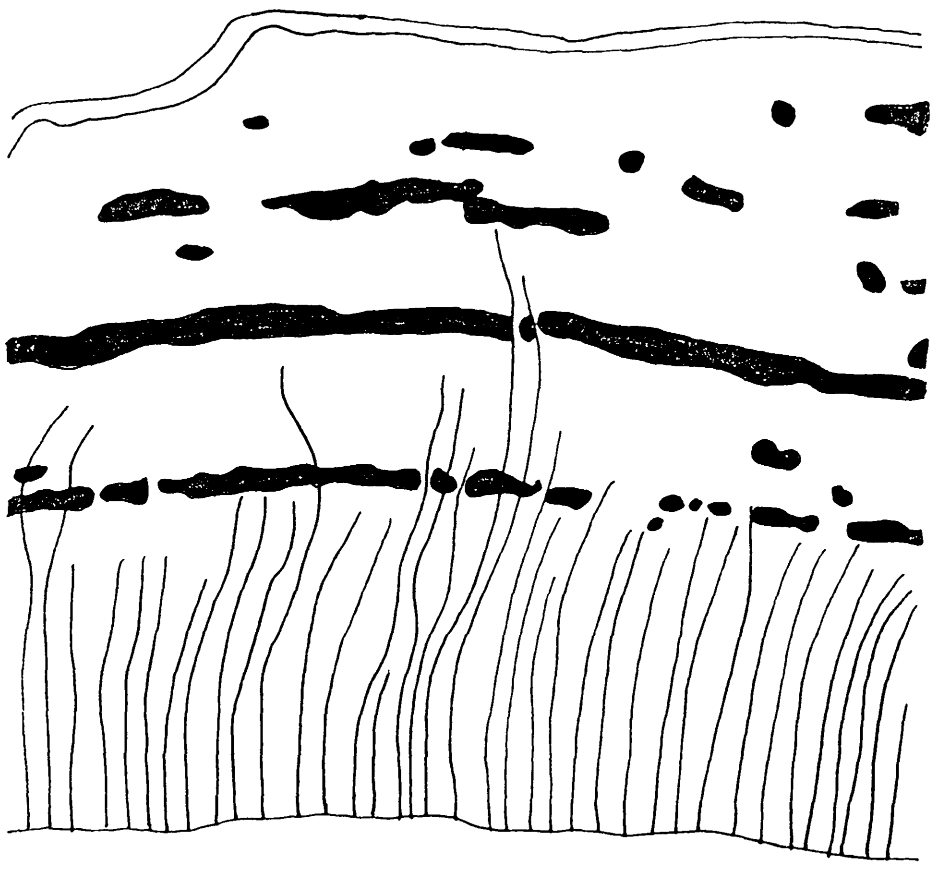

Figure 14. *Croton gratissimus (1567).* Sclerenchyma comprising fibres and sclereids.

Figure 15. *Croton megalobotrys (1728).* Sclerenchyma comprising lignified fibres, cellulosic fibres and sclereids.

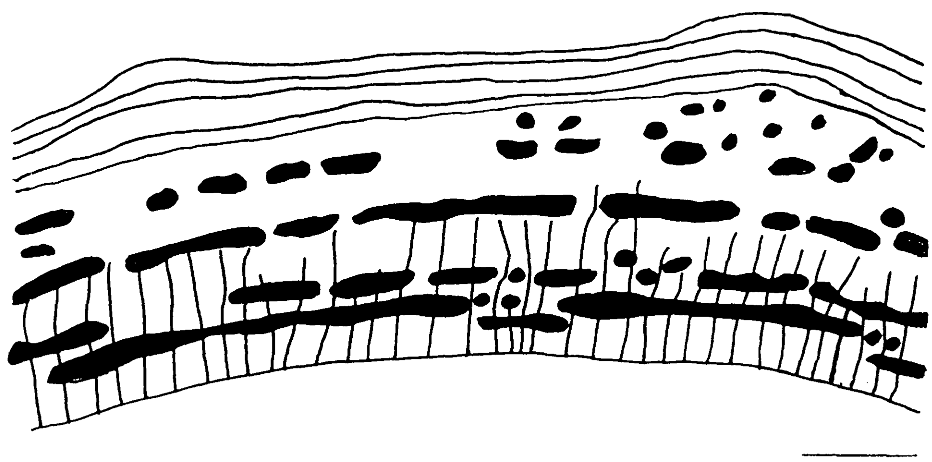

Figure 16. *Croton menyhartii (1610)*. Sclerenchyma comprising fibres and sclereids.

Figure 17. *Croton pseudopulchellus (1602)*. Sclerenchyma comprising lignified fibres, gelatinous fibres and sclereids.

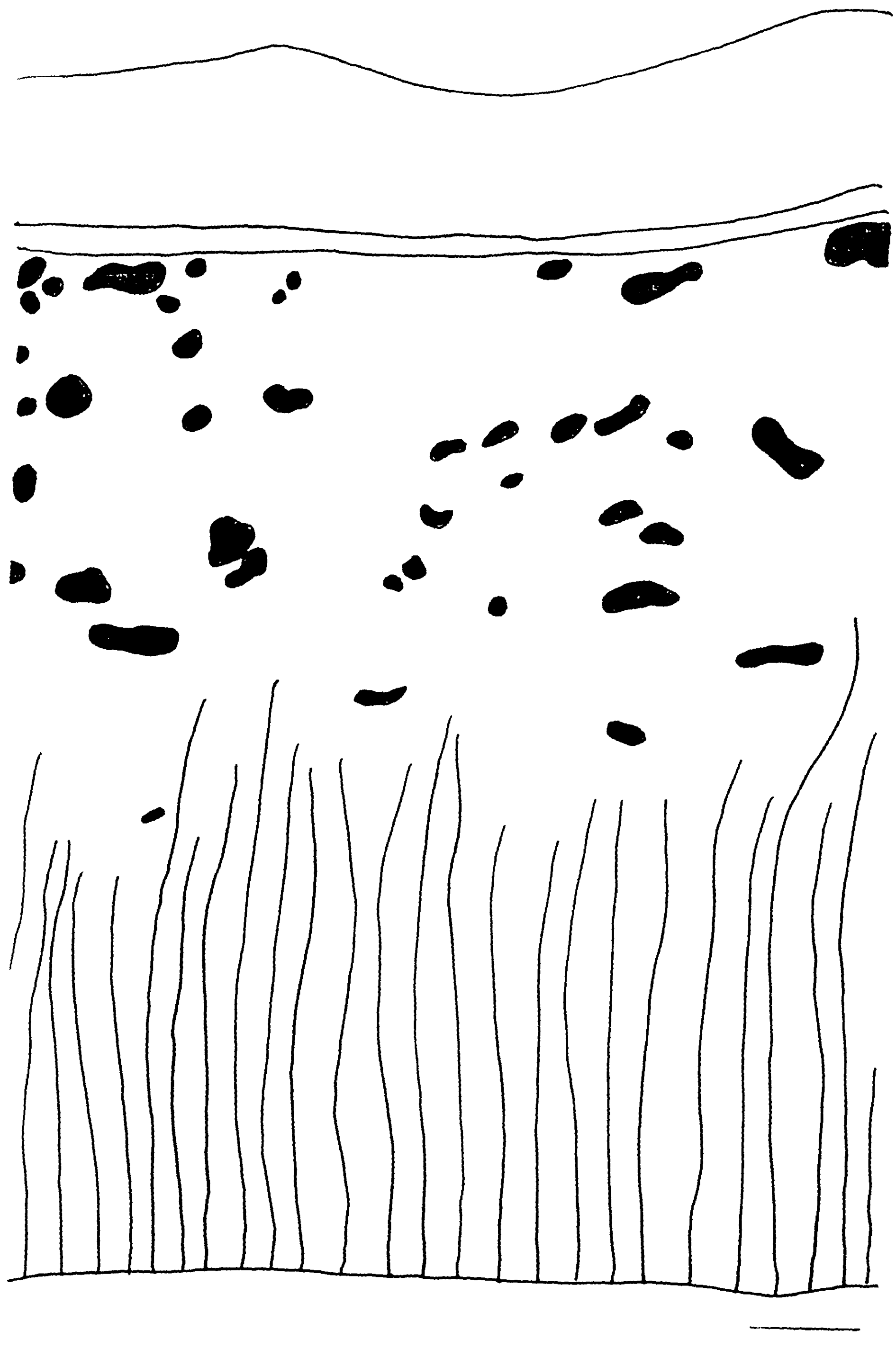

Figure 18. *Croton sylvaticus (1794).* Sclerenchyma comprising lignified and cellulosic fibres.

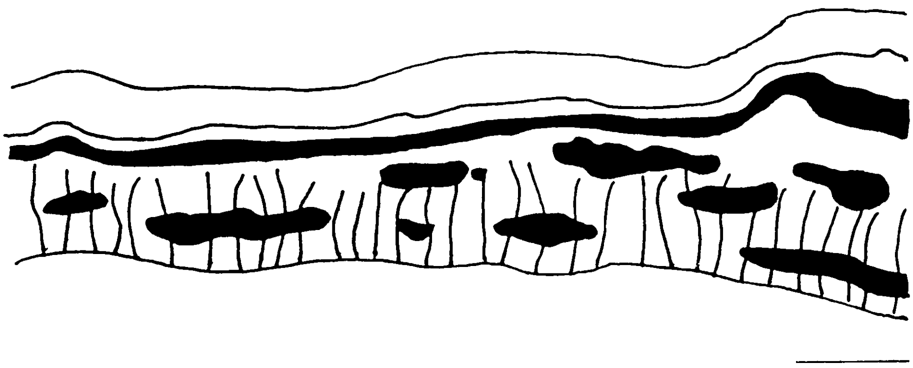

Figure 19. *Drypetes arguta (1654).* Sclerenchyma comprising sclereids and fibre-sclereids.

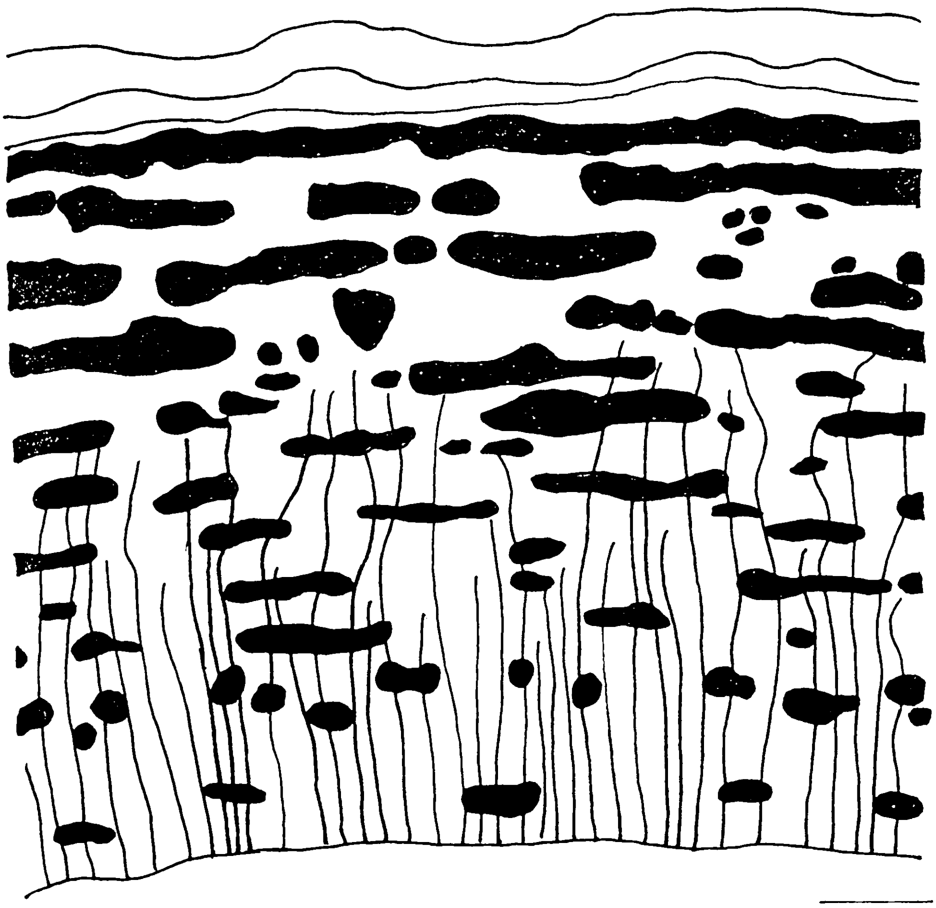

Figure 20. *Drypetes gerrardi (1513).* Sclerenchyma comprising fibres, sclereids and fibre-sclereids.

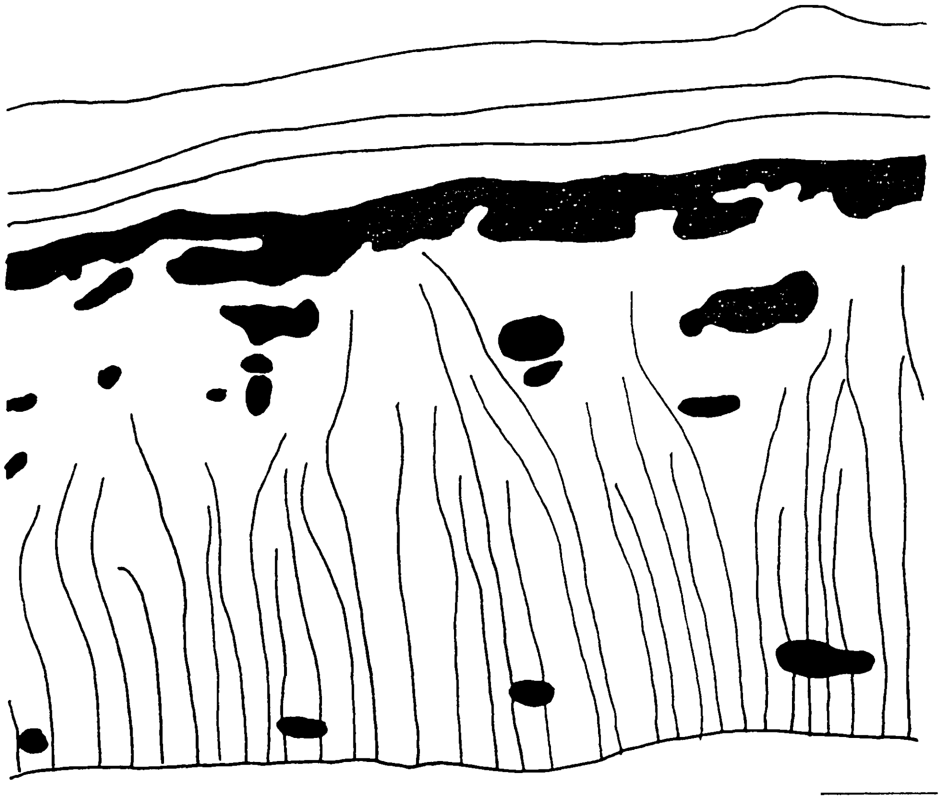

Figure 21. *Drypetes natalensis (1692).* Sclerenchyma comprising fibres and sclereids.

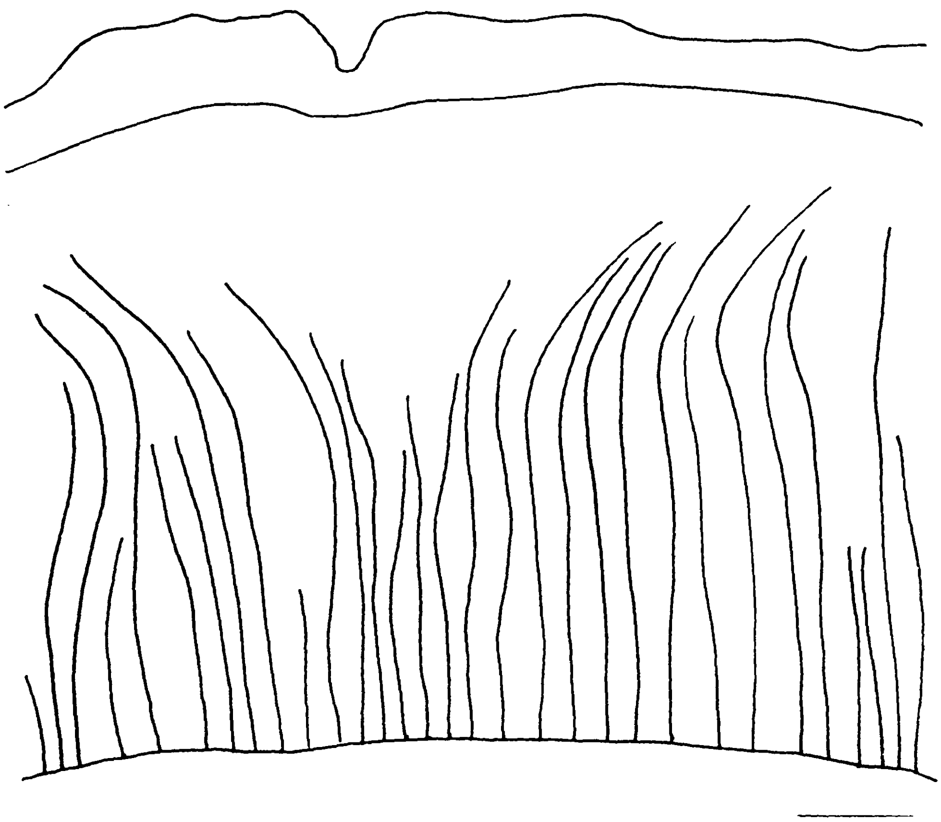

Figure 22. *Erythrococca berberidae (1676).* Sclerenchyma absent.

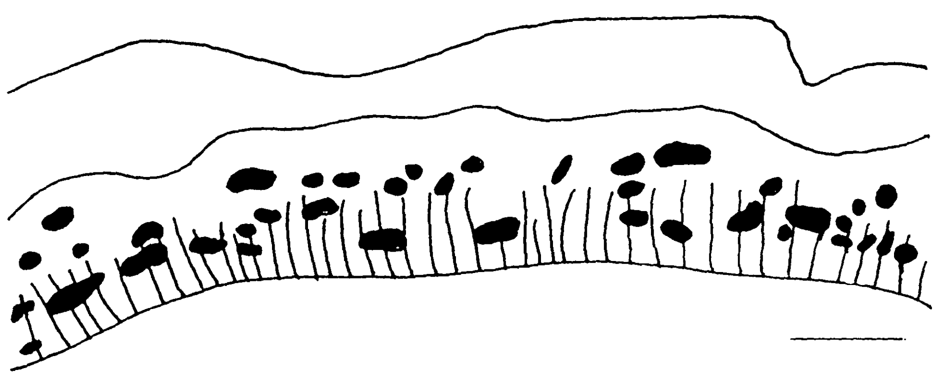

Figure 23. *Erythrococca menyhartii (1570).* Sclerenchyma comprising fibres, sclereids and fibre-sclereids.

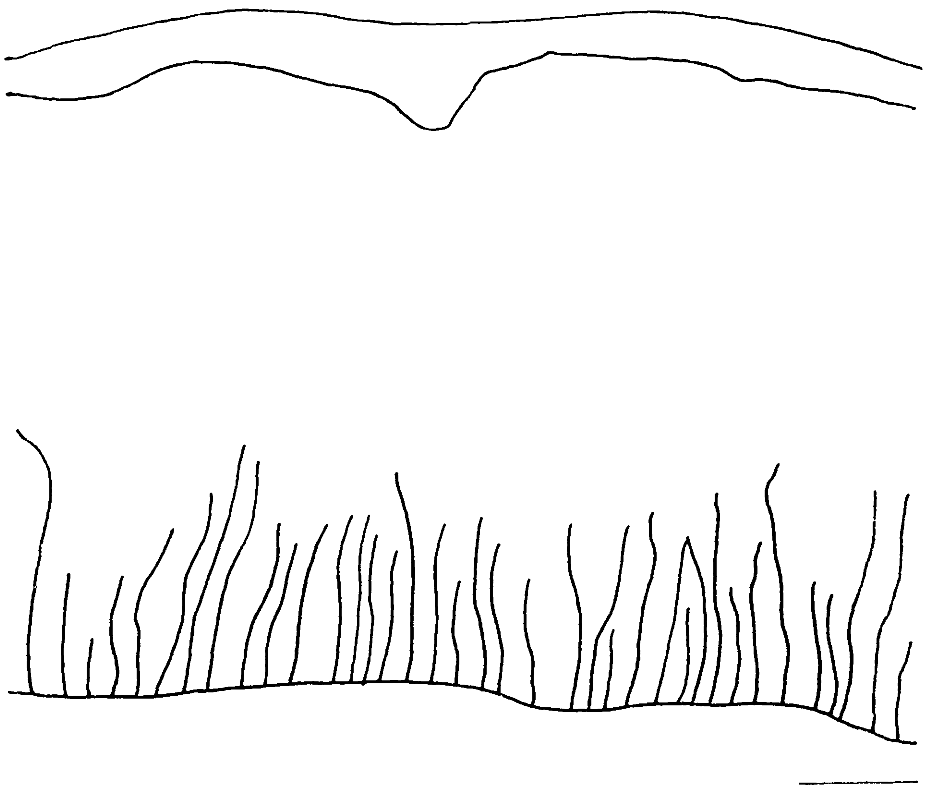

Figure 24. *Euphorbia espinosa (1603).* Sclerenchyma absent.

Figure 25. *Flueggea virosa (1579)*. Sclerenchyma comprising fibres and sclereids.

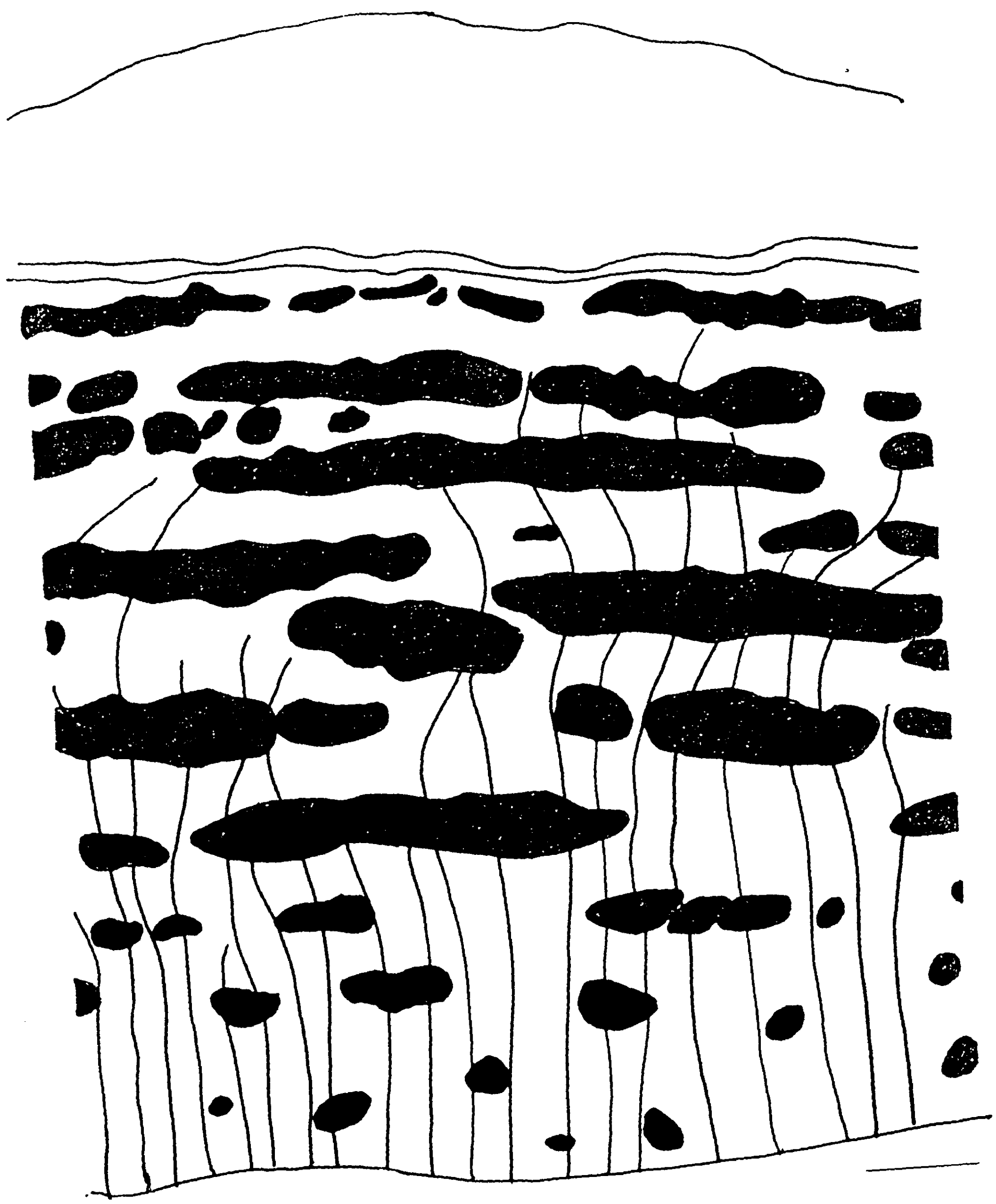

Figure 26. *Heywoodia lucens (1499)*. Sclerenchyma comprising sclereids.

Figure 27. *Hyaenanche globosa (1810)*. Sclerenchyma comprising lignified fibres, cellulosic fibres and fibre-sclereids.

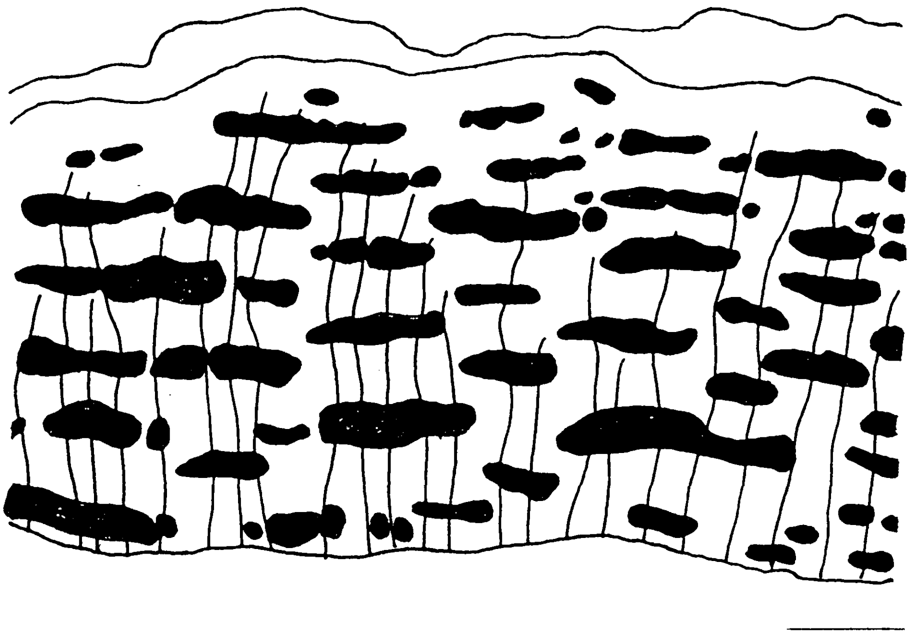

Figure 28. *Hymenocardia ulmoides (1595).* Sclerenchyma comprising sclereids and fibre-sclereids.

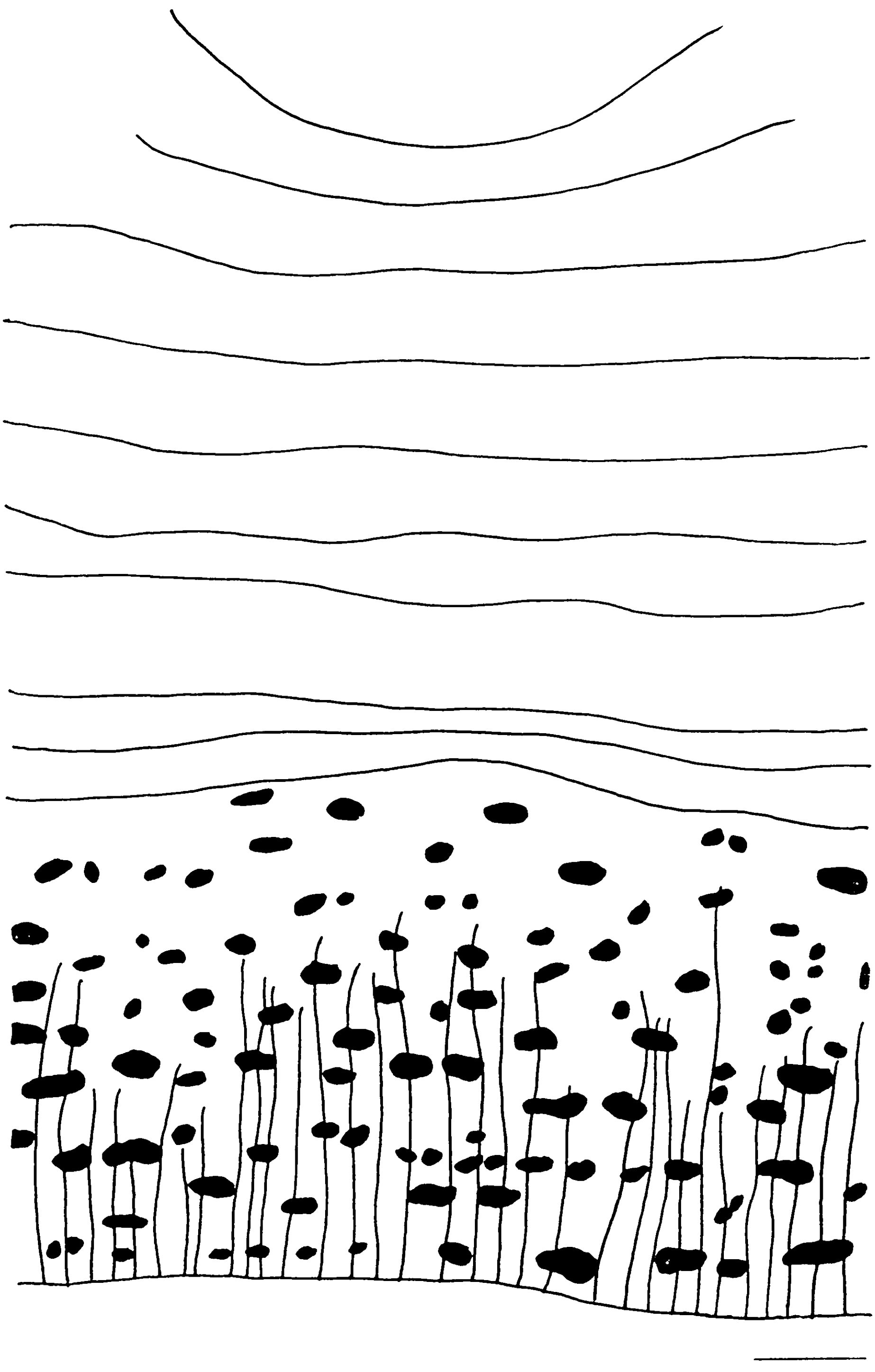

Figure 29. *Lachnostylis bilocularis (2215).* Sclerenchyma comprising fibres, sclereids and fibre-sclereids.

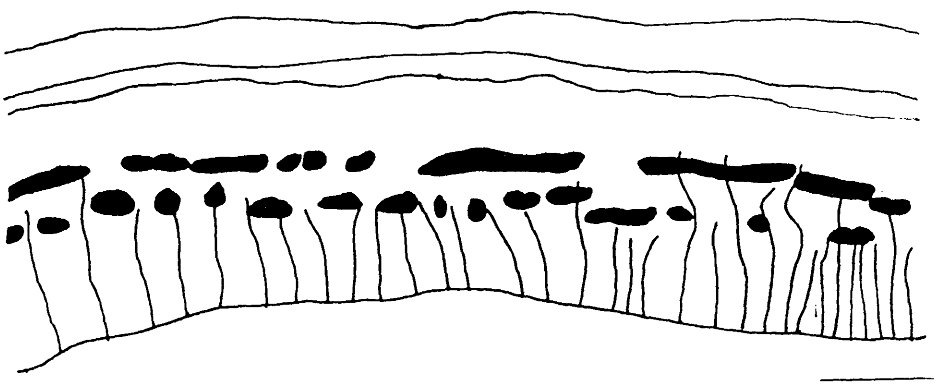

Figure 30. *Lachnostylis hirta (2157)*. Sclerenchyma comprising fibres, sclereids and fibre-sclereids.

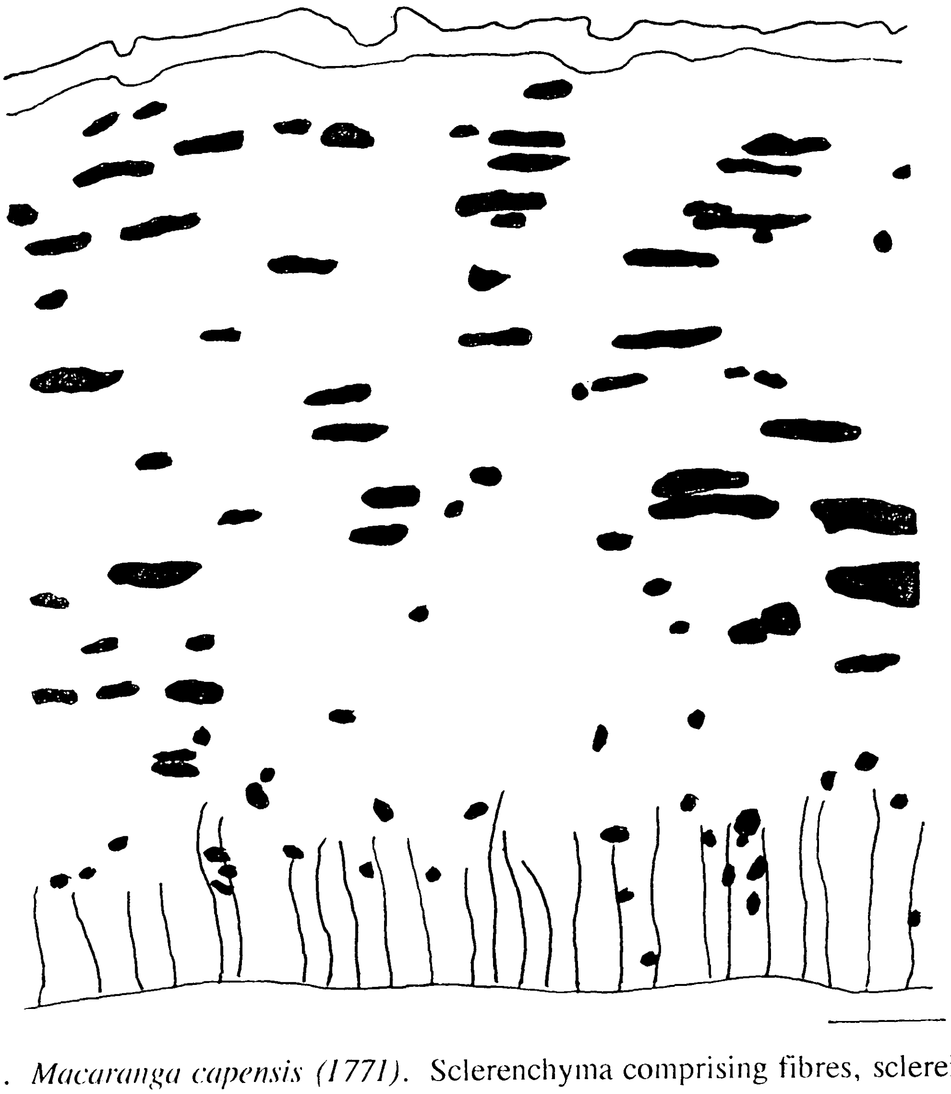

Figure 31. *Macaranga capensis (1771)*. Sclerenchyma comprising fibres, sclereids and fibre-sclereids.

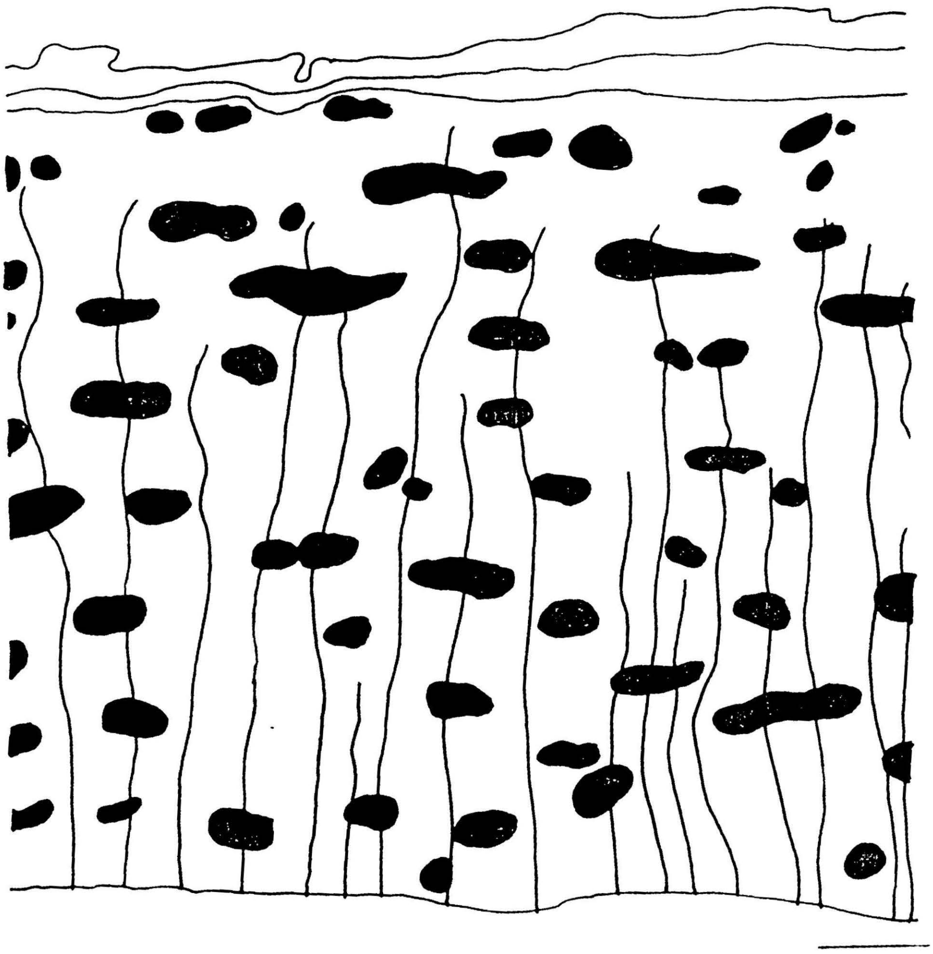

Figure 32. *Margaritaria discodea (4263)*. Sclerenchyma comprising sclereids and fibre-sclereids.

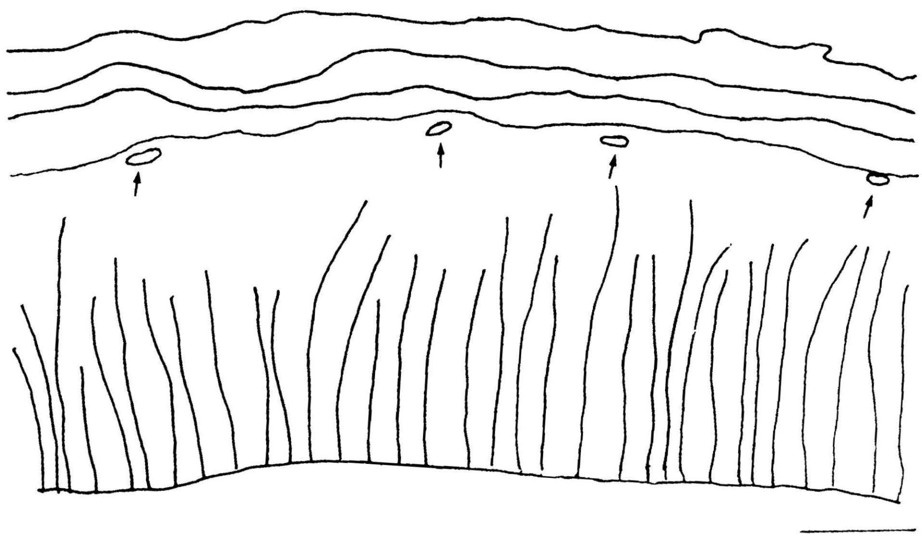

Figure 33. *Micrococca capensis (1805)*. Sclerenchyma absent.

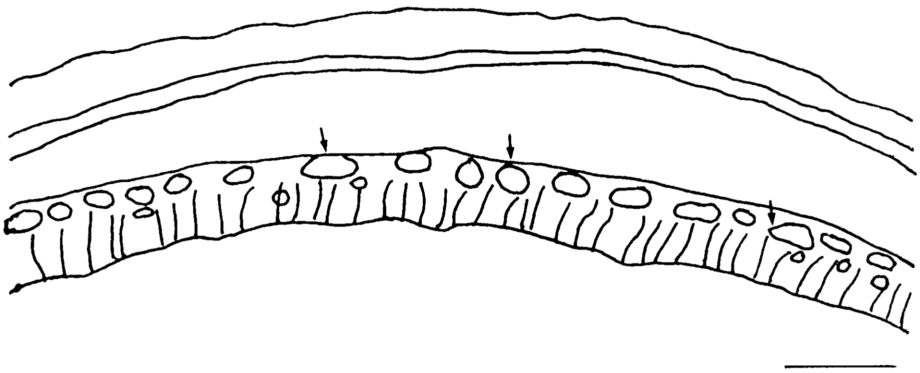

Figure 34. *Phyllanthus cedrifolius (1421).* Sclerenchyma comprising sclereids and fibre-sclereids.

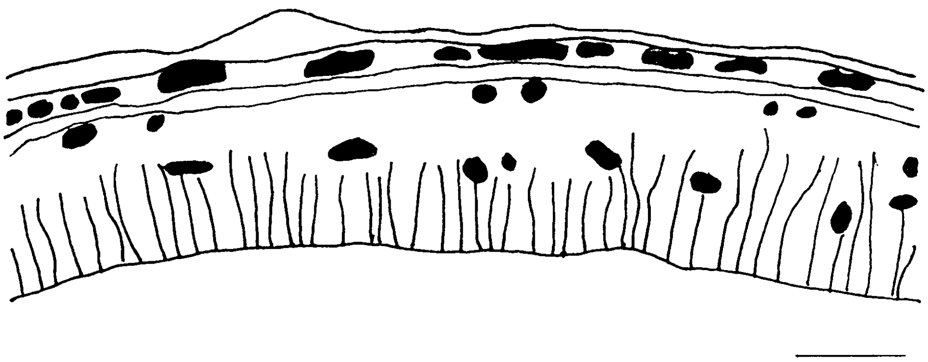

Figure 35. *Phyllanthus reticulatus (1587).* Sclerenchyma comprising sclereids.

Figure 36. *Pseudolachnostylis maprounefolia (R1543)*. Sclerenchyma comprising sclereids and fibre-sclereids.

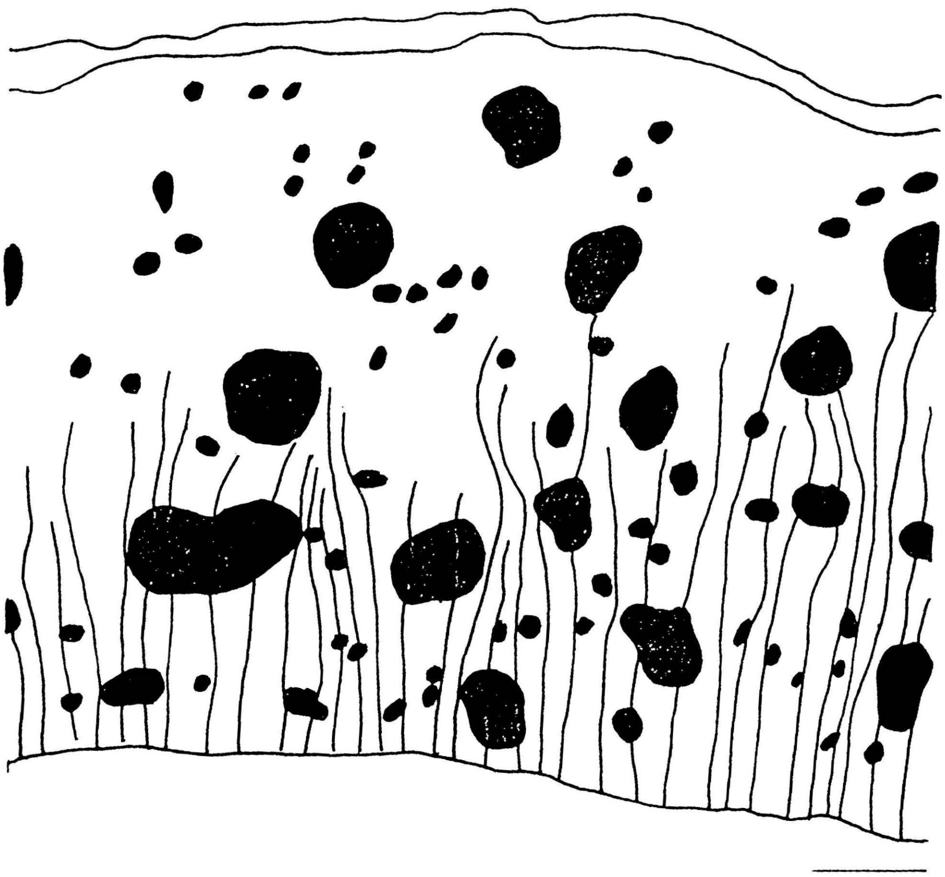

Figure 37. *Sapium ellipticum (1511)*. Sclerenchyma comprising lignified fibres, cellulosic fibres and sclereids.

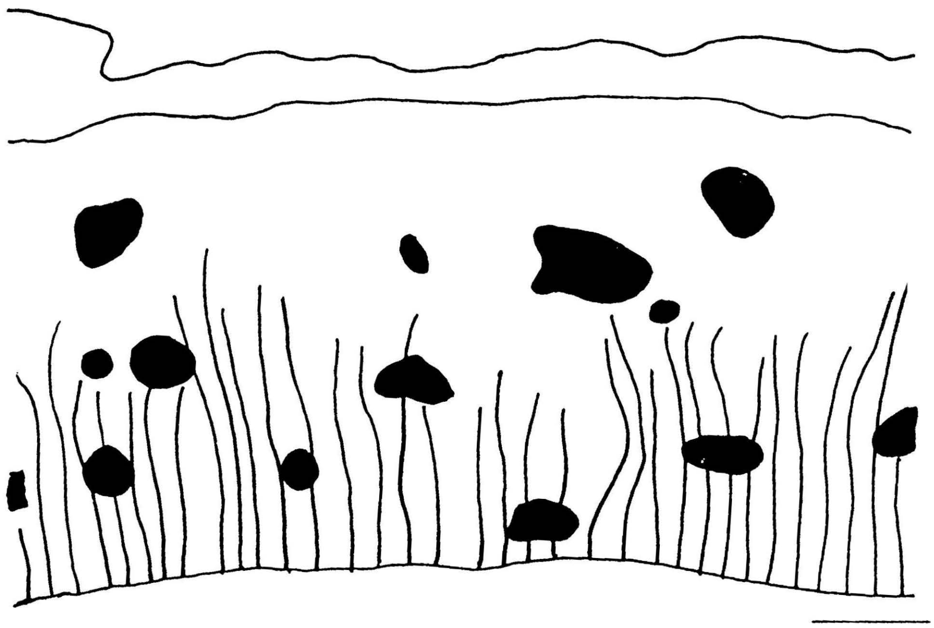

Figure 38. *Sapium integerrimum (1691)*. Sclerenchyma comprising lignified fibres, cellulosic fibres and sclereids.

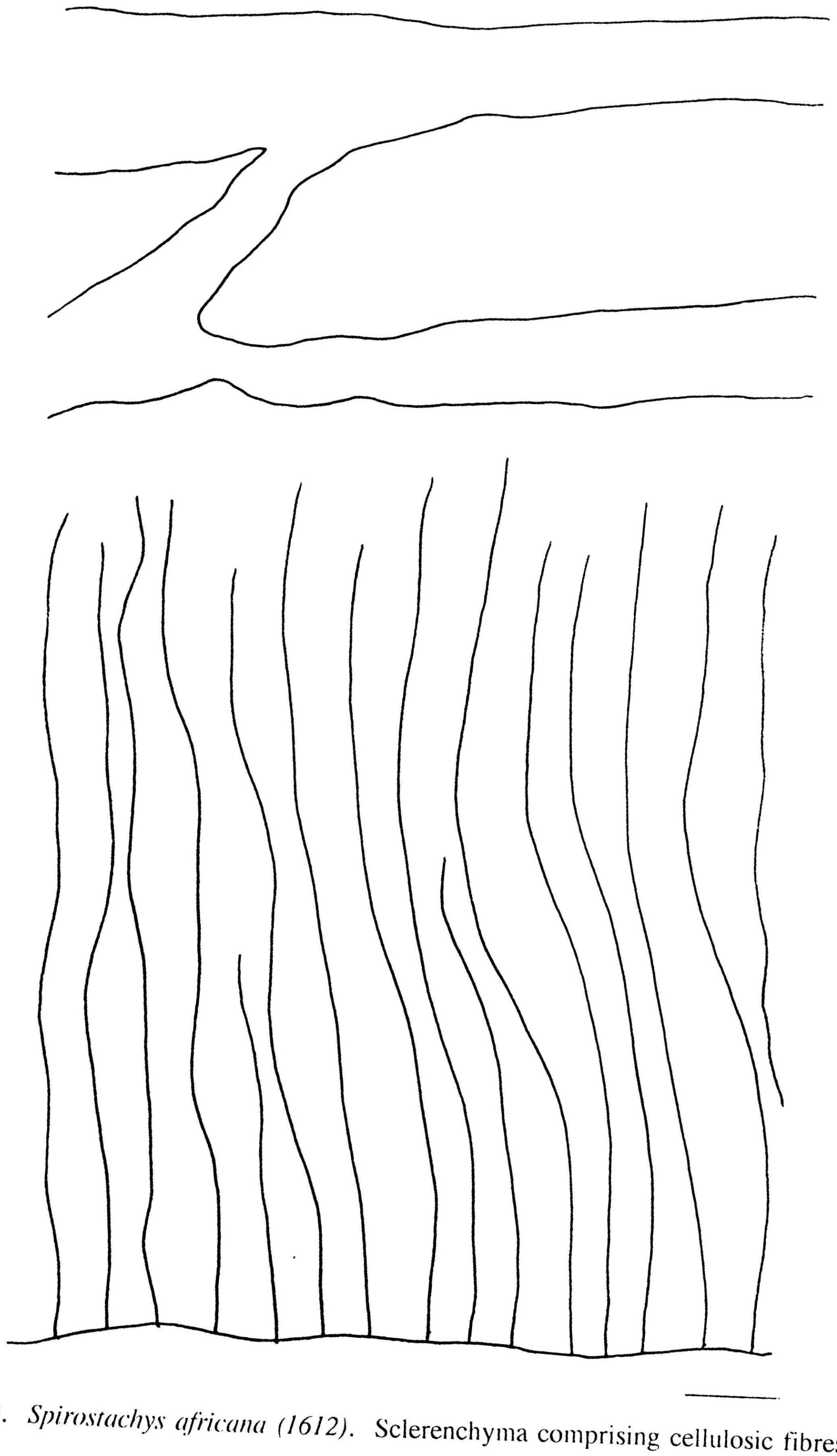

Figure 39. *Spirostachys africana (1612)*. Sclerenchyma comprising cellulosic fibres.

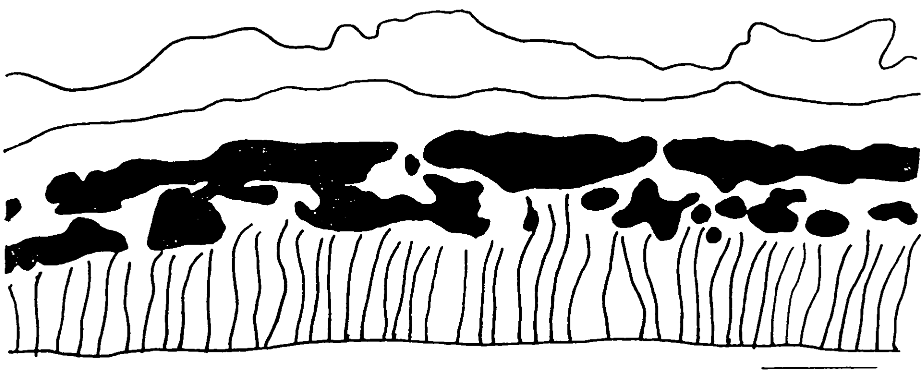

Figure 40. *Suregada africana (1654).* Sclerenchyma absent.

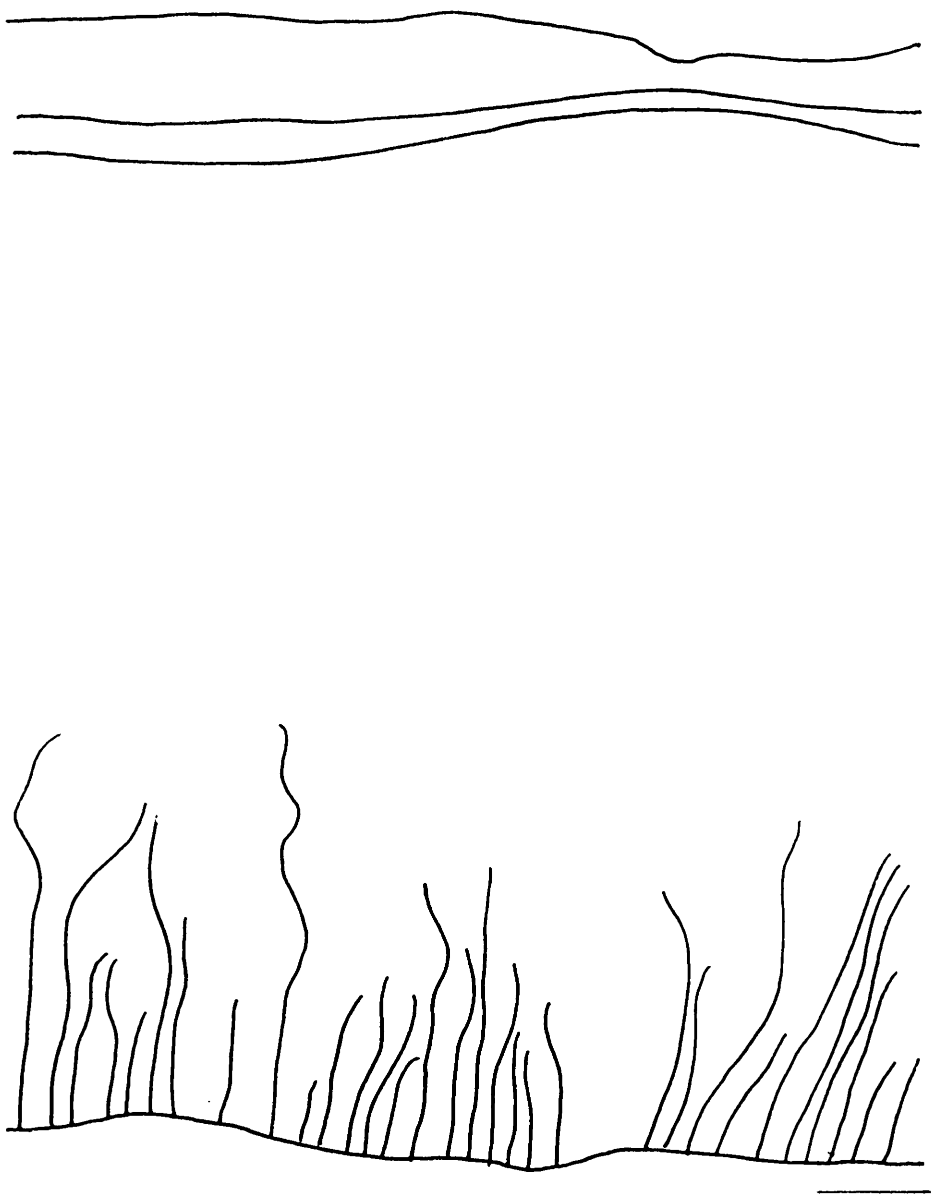

Figure 41. *Synadenium cupulare (1609).* Sclerenchyma absent.