LITHOSTRATIGRAPHY OF THE ELLIOT FORMATION (KAROO SUPERGROUP), SOUTH AFRICA

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ABSTRACT

The Late Triassic to Early Jurassic Elliot Formation is part of the Stormberg Group (Karoo Supergroup) of South Africa. The unit is significant palaeontlologically, because it preserves not only a range of vertebrate fossils, but also a plethora of ichnofossil and encompasses the boundary of Triassic and Jurassic in Southern Africa. The Formation is considered a stratigraphic equivalent of the Upper Omingonde Formation, Etjo Basin, Namibia, with the Bodibeng Sandstone Formation, Tuli Basin, Botswana, with the upper Mosolotsane Formation, Kalahari Karoo Basin. All Upper Triassic-Lower Jurassic continental red beds of South Africa, irrespective of their geographic locality relative to the main Karoo Basin are now termed Elliot Formation due to their very similar lithologic character and stratigraphic position.

Introduction

Ranging in age from Late Triassic to Early Jurassic, the Elliot Formation is part of the Stormberg Group (Karoo Supergroup) in the main Karoo Basin, and is relatively well-exposed in a ring-shaped outcrop belt surrounding the Drakensberg 'Plateau' in the Eastern Cape, Free State and KwaZulu Natal as well as in several isolated outcrop areas north of the main Karoo Basin (Figure 1). The Formation is a highly significant palaeontlolgically as it preserves not only a range of vertebrate fossils, but also a plethora of ichnofossil and encompasses the Triassic-Jurassic Boundary in southern Africa.

It is often referred to as the "Red Beds" in pre-1980 literature throughout southern Africa (e.g., Haughton, 1953; Du Toit, 1954; Ellenberger et al., 1964). Wiley (1859) introduced the concept of the Stormberg Beds, incorporating, from base to top, the Coal Measures (Molteno), Red Beds (Elliot), Cave Sandstone (Clarens) and Volcanic Beds (Drakensberg) of Dunn (1878). Johnson (1966) later proposed the name Barkly Pass Formation for the Red Beds as the Pass exposes the thickest and vertically most continuous stratigraphic succession of these red beds, but Botha's (1968) suggestion of Elliot Formation, after the nearest town in the Eastern Cape Province (Figure 1), was adopted and formally accepted by SACS in 1980 (SACS, 1980).

Stratigraphic position and age

Sandwiched between the underlying Molteno and overlying Clarens formations of the Stormberg Group, the Formation represents the longest geological time span in the history of the Karoo Supergroup as its age ranges from the Late Triassic (Carnian / Norian / Rhaetian) to Early Jurassic (Hettangian – Pliensbachian) (Visser, 1984; see discussion in Lucas and Hancox, 2001). It unconformably overlies the Molteno Formation and is conformably and gradationally overlain by the Clarens Formation (see section on Boundaries for more details).

Geological description

Basic concept and unifying features

The Formation is a red-bed succession of mudstones, siltstones and immature, fine- to medium-grained sandstones, lacking widespread marker beds, with strong red-purple-maroon diagenetic colouration, mainly of the argillaceous lithologies.

Thickness

The maximum preserved thickness of 460 to 480 m is reported from the south of the basin (Elliot type area). The Formation thins northwards, towards the KwaZulu-Natal and Free State Drakensberg, where highly variable thicknesses between 28 and 150 m occur.

Lithology

Mudrock

The mud content ranges from 54 to 60% (average 57%) in the south; and from 60 to 94% (average c. 92%) in the north. The mudrocks are clayey to silty to fine-grained sandy; grayish red (5R 4/2), pale red (10R 6/2) and greyish purple red (5RP 4/2); mainly massive and locally poorly laminated; pedogenic calcareous nodules, with frequency increasing from south to north; strongly ferruginous; elongated, angular to subangular silt to fine sand grains generally dispersed in matrix of ferruginous clay minerals.

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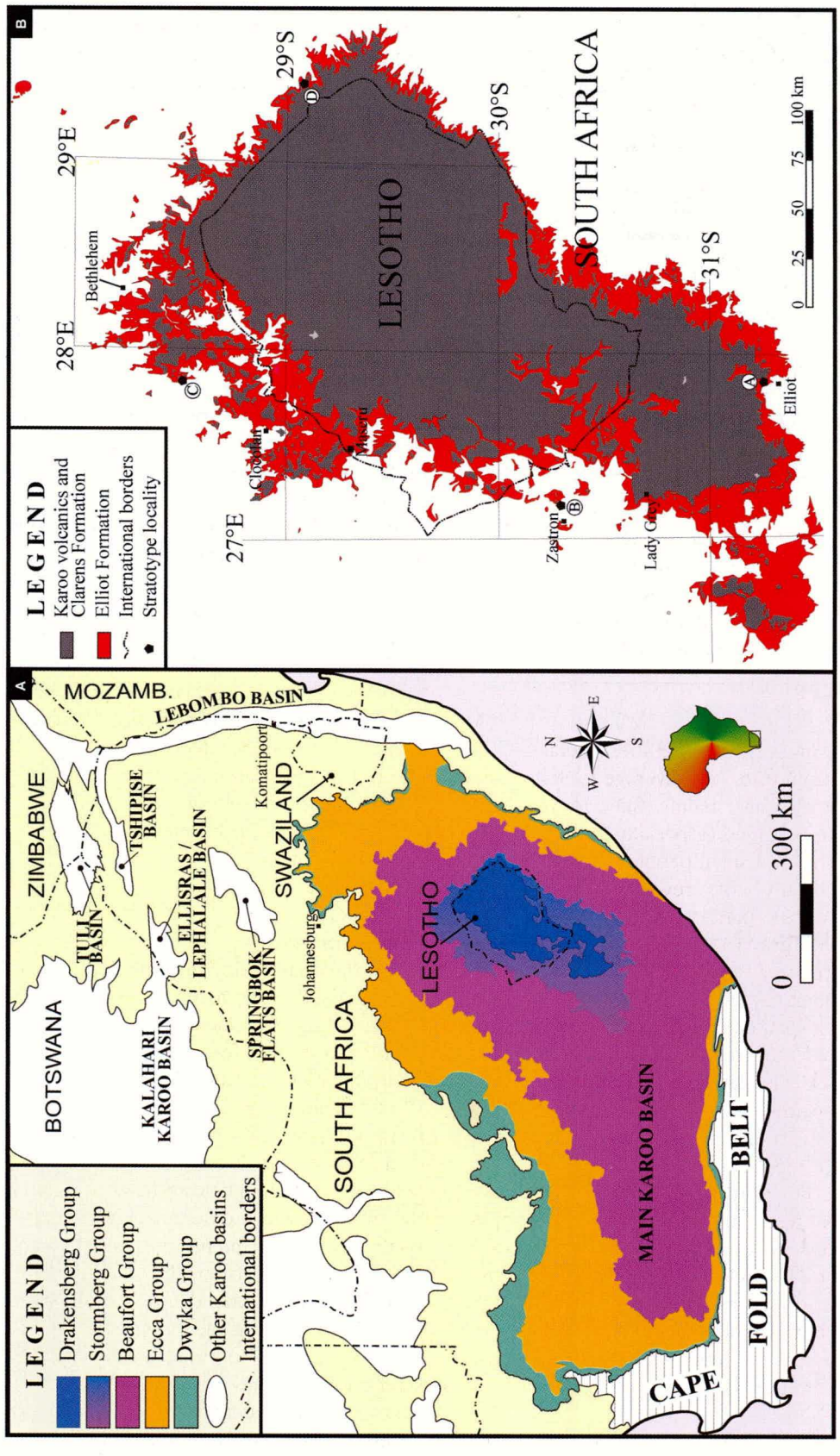

Figure 1. *Distribution maps of the Elliot Formation in South Africa (**A**) and within the main Karoo Basin (**B**). Note the positions of the stratotypes A, B, C and D as well as the location of the Karoo basins in southern Africa, north of the main Karoo Basin (modified from Johnson et al., 2006).*

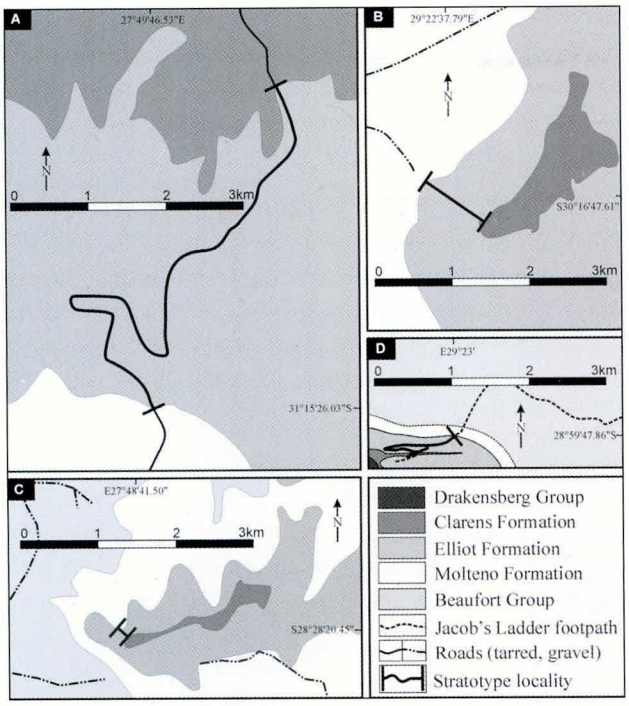

Figure 2. *Simplified geological maps of the vicinity of the stratotypes A, B, C and D of the Elliot Formation (**A**) Barkly Pass area in the Eastern Cape; (**B**) area east of Zastron in the Free State; (**C**) area between Clocolan and Bethlehem in the Free State; (**D**) area near Cathkin Park in Kwa-Zulu Natal.*

Sandstone

The sand content ranges from 40 to 46% (average 43%) in the south; and from 6 to 40% (average c. 8%) in the north. The sandstones are mainly fine- to medium-grained, lesser coarse-grained (especially in the south in the lower part), with local small pebble intraformational conglomerates (mostly of reworked pedogenic nodules in the upper part); mainly dusky yellow (5Y 6/4) to yellowish gray (5Y 7/2); locally ferruginous or calcareous (matrix material); texturally and mineralogically immature, mainly lithic arenites in the lower part and feldspathic wackes in the upper part; lenticular (lower part) to sheet-like (upper part) bodies <1 m to 15 m thick with lateral extents from 15 m to several hundred metres, with common erosive bases marked by pebbles, grit and mudclasts. The sandstones also contain trough (more common in south) and planar (more common in north) cross-bedding, lesser planar stratification (common especially in the upper part), minor ripples (more common in the upper part), invertebrate trace fossils (relatively higher diversity and abundance in the upper part; Bordy et al., 2004b), and slumped bedding. The lower sandstone boundaries are erosive above scoured mudrock surfaces, and the upper boundaries are sharp.

Palaeontology

Vertebrate fossils are fairly common. As a very general rule, larger sauropodomorph dinosaurs in the lower part, and more gracile forms upwards (Haughton, 1953; Ellenberger et al., 1964; Kitching and Raath, 1984). Other fauna include turtles, fish, amphibians, crocodilians, advanced therapsids and early mammals (Abdala et al., 2007). Relatively abundant fossil wood and crustaceans (conchostracans, ostracods) also occur (Du Toit, 1954; Tasch, 1984). Diverse trace fossil record (Olsen and Galton, 1984; Smith and Kitching, 1997). Contains the oldest known dinosaur eggs (Reisz et al., 2012).

Genesis

Overall, the Formation was deposited in a fluvio-lacustrine environment. The two contrasting types of sandstone body geometry and composition in the lower and upper parts of the Formation resulted from different fluvial depositional styles. In the lower part, the sandstones resemble multi-storey, asymmetrical channel-fills, interpreted as deposits of perennial, moderately meandering fluvial systems (Botha, 1968; Visser and Botha, 1980; Smith et al., 1993; Bordy et al., 2004b). In the upper part of the Formation, the mostly tabular, multi-storey sheet sandstones and associated facies resulted from ephemeral fluvial, playa lake and loessic aeolian processes (Visser and Botha, 1980; Eriksson, 1984, 1985; Smith et al., 1993; Bordy et al., 2004b). In the northern, more distal Drakensberg regions, where the lower part is diminished in thickness, the Formation is dominated by an association of seasonal to ephemeral anastomosing rivers with loessic floodplain fines, and semi-arid sheetflood deposits (Eriksson, 1984, 1985). The fluvial style differences were generated by changes in the tectonic setting (e.g., tectonic pulses and associated subsidence rates) and climatic conditions (e.g., aridification).

Boundaries

Lower boundary

It is regionally unconformable, sharp. Systematic regional field work focused on this contact found no interfingering (or facies equivalence) between the Molteno and Elliot formations (in contrast to the views on a gradational relationship between the Molteno and Elliot formations of Turner, 1977 p. 242; Christie, 1981 p. 12; Eriksson, 1984 p. 237; Cole, 1992 p. 95; Anderson et al., 1998 p.392). The unconformity is characterized by flat lying strata both below and above, and it is indicated by the following differences that occur in vertical sections across it: architecture of the sandstone units, palaeocurrent dispersal directions, abundance pedogenic indicators, detrital composition, body and trace fossil content, including the taphonomy of the reserved fossils (Bordy et al., 2005). The underlying sandstones of the Molteno Formation are generally coarser, thicker, laterally more persistent and tabular in shape, and are thus distinguishable from the sandstones in the lower Elliot which tend to be asymmetrical channel-shaped bodies.

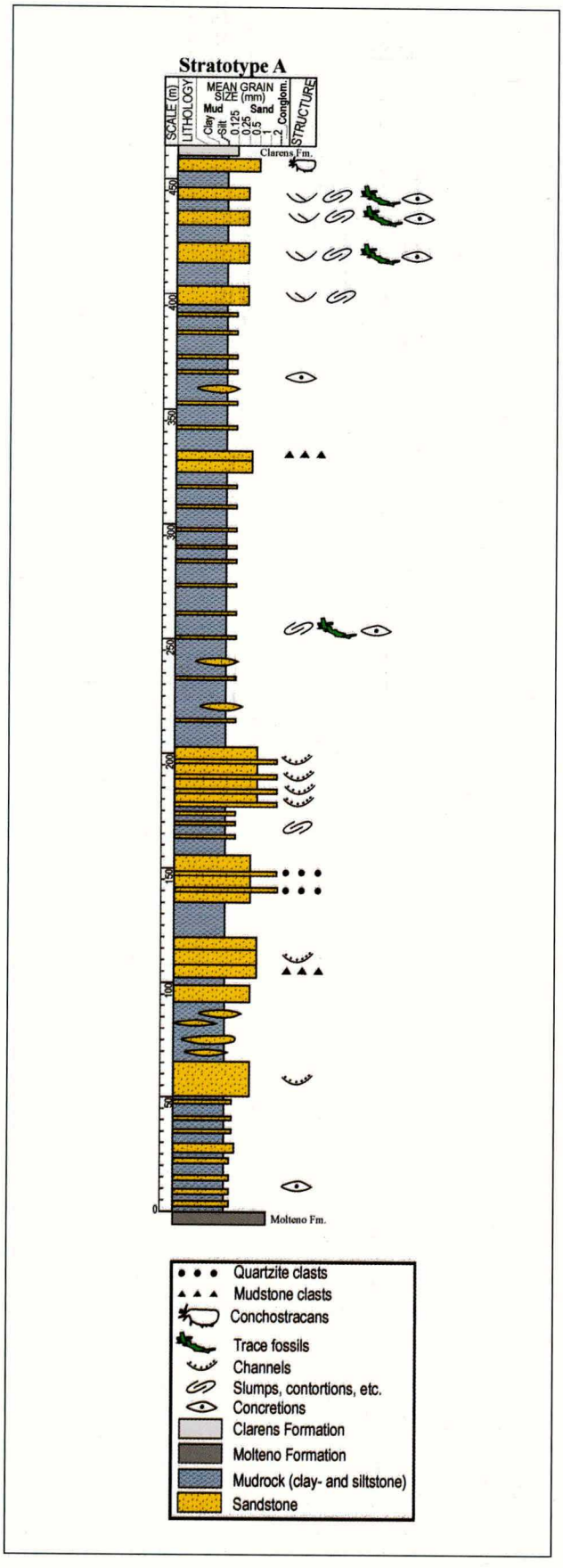

Figure 3. *Holostratotype (stratotype A) of the Elliot Formation in the Barkly Pass (Eastern Cape; S31°15'23", E27°49'45"). The section was measured by Visser and Botha (1980; Figure 2).*

Upper boundary

It is conformable and gradational, with an interval of several tens of metres thickness in both the upper Elliot and lower Clarens formations being marked by interbedded Elliot red bed and Clarens pale-coloured fine sandstones. Definition of contact is thus problematic and has been placed by certain workers at the base of the first Clarens-type sandstone, or at the top of the uppermost Elliot-type red mudrock; stratigraphic height differences of several tens of metres will thus result. Eriksson (1985) placed the boundary where sandstones with large- to very large cross-bedding become predominant in terms of thickness over interbedded subordinate red coloured mudrocks, i.e. at the base of the relevant Clarens sandstone bed.

Lateral boundary

The Elliot Formation shows no lateral transitions into either underlying Molteno or overlying Clarens formations (Figure 1).

Subdivision

No formal subdivision has as yet been proposed. However, based on changes in the sedimentary facies architecture, palaeocurrent pattern, sandstone composition, isopach trends as well as body and trace fossil content, a regional, but informal lithostratigraphic subdivision of the Elliot Formation is possible. These informal lower and upper members are separated by an unconformity (i.e., a paraconformity which is a second order sequence boundary – see Bordy et al., 2004a and b).

Regional aspects

Geographic distribution is illustrated in Figure 1.

Lateral variation

It attains its maximum thickness in the Barkly Pass area (Figure 1) (see section on Geological description). From here, it is documented to thin progressively northwards, reducing gradually to locally less than 30 m in the northeastern Free State and northwestern KwaZulu Natal (Figure 1; Bordy et al., 2004a). The northward thinning in the lower part of the Formation is more pronounced than in the upper part. This prominent south to north decrease in overall thickness is accompanied by a northward decrease in sandstone percentage and sandstone maturity. Evidence for gradually more arid palaeoenvironment towards the north both in the lower and upper parts of the Formation is well-documented.

Correlation

The Elliot Formation is correlated chrono-stratigraphically with the Upper Omingonde Formation, Etjo Basin, Namibia, with the Bodibeng Sandstone Formation, Tuli Basin, Botswana, with the upper Mosolotsane Formation, Kalahari Karoo Basin, Botswana (Smith et al., 1993; Bordy et al., 2010). All Upper Triassic-Lower Jurassic continental red beds of South

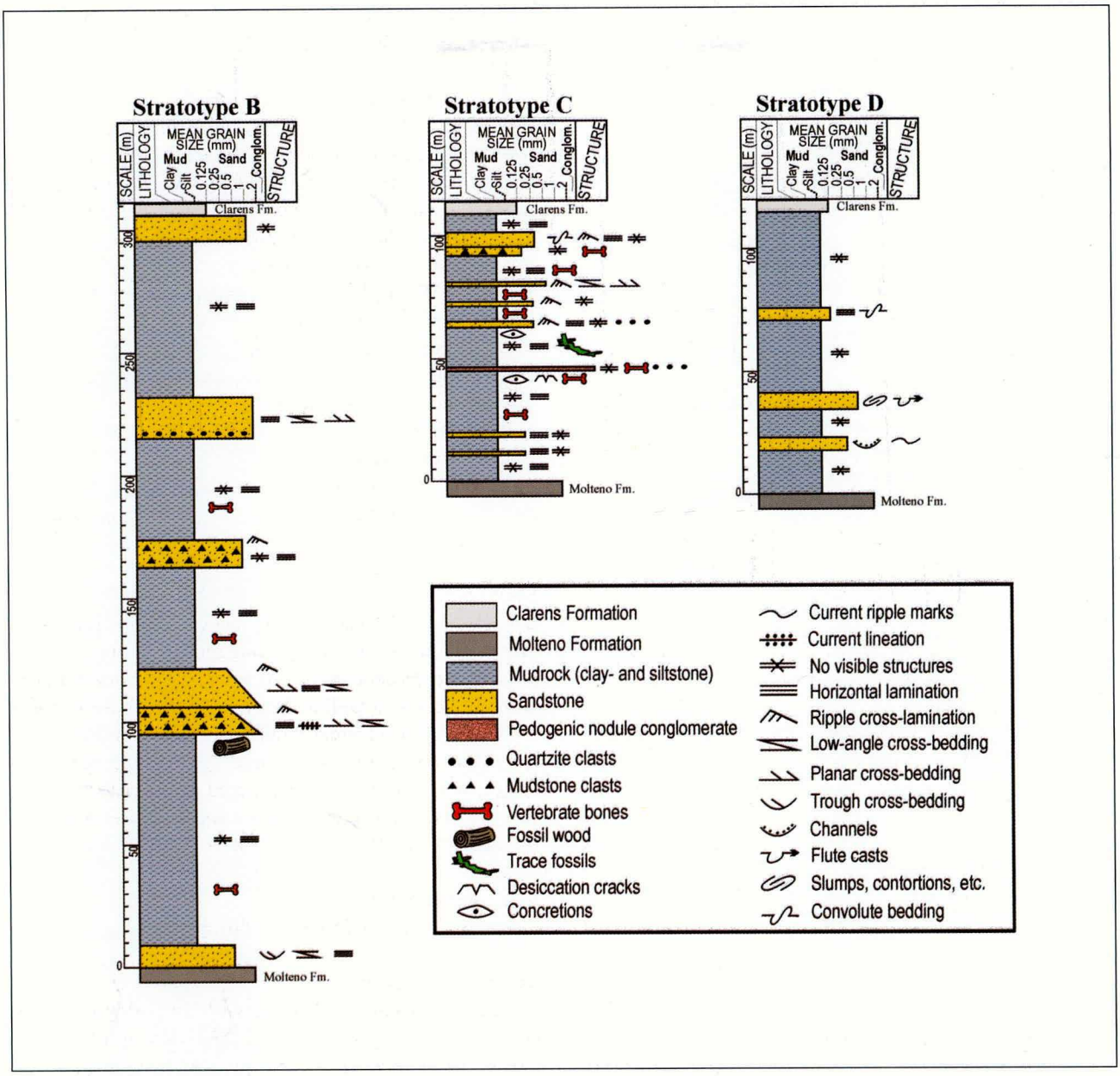

***Figure 4**. Stratigraphic sections of the Elliot Formation: Stratotype (**B**) S30°16'52", E27°10'25"; east of Zastron; Free State. Stratotype (**C**) S28°28'29", E27°48'42"; between Clocolan and Bethlehem; Free State. Stratotype (**D**) 29° 0'24.29"S, 29°22'24.06"E; Cathkin Park; Kwa-Zulu Natal. Stratotypes B and C were measured by E.M. Bordy (2003); stratotype D was measured by P.G. Eriksson (1984).*

Africa, irrespective of their geographic locality relative to the main Karoo Basin (Figure 1), are now termed Elliot Formation due to their virtually identical diagnostic lithologic character and stratigraphic position. This change affects the upper part of the Irrigasie Formation (Worthing Member – Springbok Flats Basin); the entire Lisbon Formation (Ellisras/Lephalale Basin); the entire Nyoka Formation (southern Lebombo Basin), the entire Bosbokpoort and the Red Rocks Member of the Clarens Formation (northern Lebombo, Tshipise and Tuli Basins) (Figure 1).

Stratotypes

The unit holostratotype is located in the Eastern Cape Province, along the road cuttings and outcrops adjacent thereto on the Barkly Pass, about 9 km north of the town of Elliot (see Botha, 1968) (Figures 1, 2A and 3). Regional dip is about 3 to 7° to the north for the lower part of the Formation, with the upper half being approximately horizontal. Outcrop quality is moderate to poor with the predominant mudrocks being heavily weathered, but dolerite intrusions are minimal. Reference stratotypes are shown for the area east of Zastron in the Free State (Figures 2B and 4); for the area between Clocolan and Bethlehem in the Free State (Figures 2C and 4) and for the Kwa-Zulu Natal Drakensberg region (Cathkin Park; Figures 2D and 4; see Figure 1. for locations within the basin).

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