Fossil trees from the basal Triassic Lebung Group at the Makgaba site, west of Mokubilo, Botswana

M. De Wit[1], M. Bamford[2] & C. Van Waarden[3]

[1]*Tsodilo Resources Ltd and University of Pretoria*

[2]*Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, Johannesburg*

[3]*Marope Research, Francistown, Botswana*

Received 18 July 2017. Accepted 19 February 2018

Fossil wood samples were collected from an area underlain by Karoo Supergroup rocks along the southern edge of Sua Pan in east central Botswana. From the local stratigraphy it suggests that these fossils have been derived from the Mosu sandstones that occurs at the base of the Mosolotsane Formation and which is time-equivalent to the Molteno Formation in South Africa that is of Triassic age. Based on the arrangement of tracheid pits the fossil wood has been identified as *Agathoxylon*, and most likely *Agathoxylon africanum*. This species has a Permian to Triassic time range in southern Africa and probably is the first published record of *Agathoxylon africanum* in Botswana.

Keywords: *Agathoxylon*, Molteno flora.

INTRODUCTION

In 2016, the declared palaeontological heritage site on the southern edge of Sua Pan and below the Mosu Escarpment was visited to collect fossil wood samples. This Makgaba (Simanentsa) fossil tree site 16-A4-3 (Table 1) is just north of the Moriti wa Selemo bush camp (Fig. 1). This camp is 7 km east of the Tlalamabele veterinary gate on the A30 and some 95 km east of Orapa (Fig. 2). Because the site is a protected monument, permission was obtained from the Botswana National Museum in August 2016 (Ref: NM 6/1/1 II (100)) to remove samples for identification and age determination.

The objective was to place these Makgaba fossils in their original stratigraphic context by field investigation of the local geology and species identification of wood samples. Presently, the National Monument sign at the Makgaba site refers to it as 'these rare fossils are remnants of ancient trees that turned into solid rock some 50 million years ago.' Such mis-information is misleading and in an attempt to improve local tourism the signage will be updated and information supplied to the local tourism authority.

*Author for correspondence. E-mail: dewit@icon.co.za

MATERIALS AND METHODS

Description of Makgaba fossil tree site

The Makgaba site is roughly 3.5 km north of the Moriti wa Selemo camp (Fig. 2). At the site there are four places where the fossil wood occurs (Table 1). However, the manager of the Moriti wa Selemo Camp has located more fragments of fossil trees on the Mosu scarp to the south and west of the Makgaba site. Coordinates of each wood occurrence were taken with a Garmin 62 handheld GPS using the UTM WGS84 (Zone 35K) datum (Table 1).

The fossils at the Makgaba site listed in Table 1 are located on the slopes of a small hill within an embayment of the pan and is surrounded by higher ground to the west, south and east. A scarp, which separates the higher ground from this embayment is some 50 m in height, and is the easterly extension of the Mosu Escarpment which reaches its maximum elevation of some 91 m east of Mosu. The escarpment and the hill are composed of Karoo

Table 1. Position of fossil tree samples at the Makgaba site (using the UTM WGS84 (Zone 35K) datum).

Location	Eastern	Northern	Dimensions (L, W, H) in cm	Comment
Tree 1 – T1	0426747	7647494	55 × 50 × 40	Loose boulder
Tree 2 – T2	0426785	7647494	30 × 45 × 25	Loose boulder
Tree 3 – T3	0426784	7647629	200 × 50 × 30	'Near' *In situ*
Tree 4 – T18	0426788	7647691	Many fragments	Loose pebbles

***Palaeontologia africana* 52: 194–200 — ISSN 2410-4418 [Palaeontol. afr.] Online only**
Permanently archived on the 22nd of March 2018 at the University of the Witwatersrand, Johannesburg, South Africa.
The article is permanently archived at: https://hdl.handle.net/10539/24149

Figure 1. Site 'Fossil Tree 3' of broken up fossil tree trunk. Hammer 30 cm in length for scale.

Supergroup rocks (Stansfield 1973) that are partly covered by scree material.

None of the fossil tree specimens appear to be embedded in the Karoo Supergroup strata and are not found in their living positions. The largest however, the T3 fossil, occurs as a horizontally lying trunk broken into several boulder size fragments. It is almost 2 m in length (Fig. 1) and totally unabraded. This suggests that this specimen, after been exhumed from Karoo sediments at the site, has experienced little or no post-exhumation movement. We are therefore confident that these can be referred to as 'nearly' in situ (Fig. 1). The T1 and T2 fossils are abraded

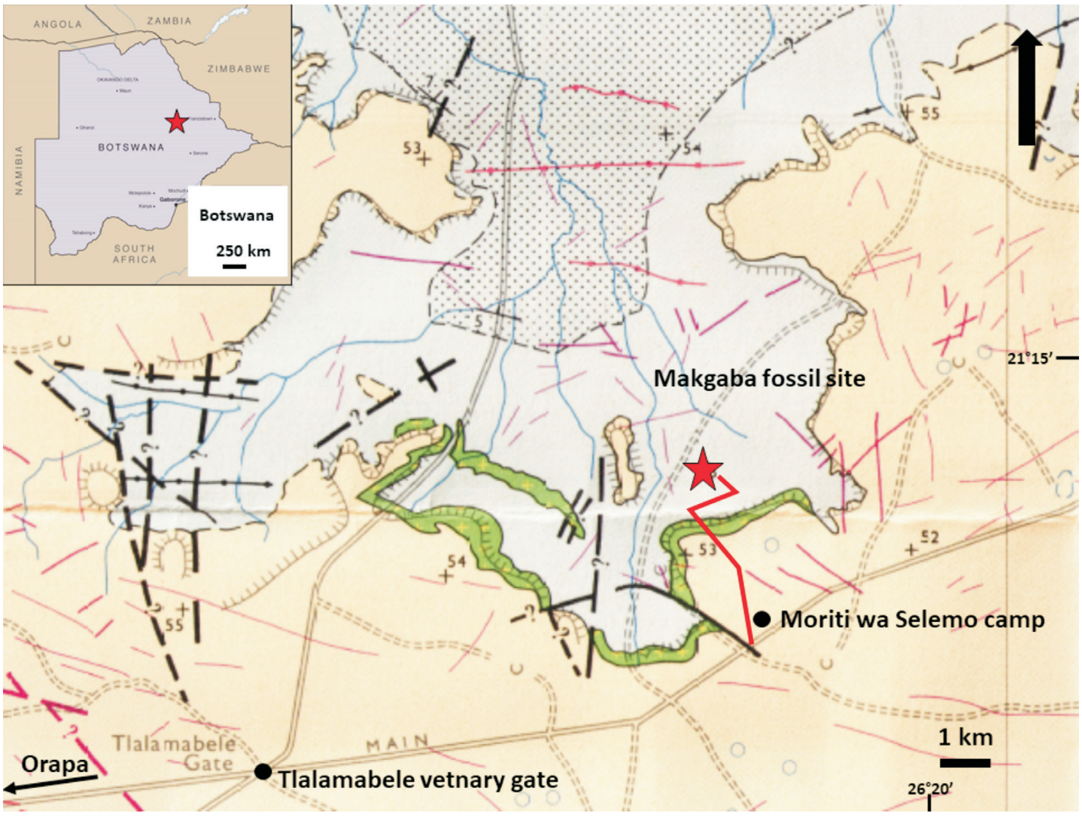

Figure 2. Local geology (From: Quarter Degree Sheet 2126A, Tlalamabele, Geological Survey of Botswana, scale 1:125,000, with brief description of the geology by G. Stansfield, 1973). Pale yellow – Ntane Sandstone Formation; pale blue – Tlhabala Formation and Tlapana Formation, stippled where carbonaceous ; green – dolerite sills; thick black lines – faults; red lines with dots – probable dyke; purple lines – linear photo feature; red star – small hill with fossil tree occurrences. Thick red line is approximate position of section in Fig. 5.

and found at lower levels while the T18 site is composed of many small fragments that have been collected and dumped at this site.

Local geology

According to the geological map of the quarter degree sheet Tlalamabele 2126A (Fig. 2) the fossil trees occur close to the contact of Upper Ecca Group Tlapana mudstones, and the overlying sandstones of the Lebung Group (Fig. 2) (Stansfield, 1973).

Stansfield (1973) describes the mudstones of the Tlapana Formation (Fig. 2), the uppermost formation of the Ecca Group in the Tlalamabele area, as generally being non-carbonaceous. These are light-grey to bluish in colour and weather to light-yellow on surface. According to Smith (1984) the lower part of the Tlapana Formation is carbonaceous and contains coal seams. The non-carbonaceous upper part of the Tlapana mudstones has been referred to by Smith (1984) as the Tlhabala Formation (Table 2). The non-carbonaceous grey to brown mudstones of the uppermost part of this formation contain limestone bands and septarian nodules, and is known as the Kautse Member (Smith 1984). These have been logged in borehole N4/1 approximately 8 km southeast of Mosu and some 23 km west of the fossil tree site (Stansfield 1973). Smith (1984) suggests that the Kautse Member is limited in extent and displays some rapid lateral facies changes. In another borehole N1/3 (Smith 1984), estimated to be some 10 km to the southeast of the fossil site, the lowest part of the Tlhabala Formation is overlain directly by the Ntane Sandstone Formation and there are no Kautse Member rocks present. According to Stansfield (1973) the upper Tlhabala Formation, in places lies directly and conformably on the 'non-carbonaceous' mudstones of the upper Tlapana Formation. The overlying Lebung Group is subdivided into the Mosolotsane and Ntane Formations (Table 2). On the scarp near Mosu the proximal sandy facies of the Mosolotsane Formation comprising immature, coarse-grained, cross-bedded sandstones with isolated pebbles that is weakly cemented by 'iron ores' (Stansfield 1973). Smith (1984) refers to these facies as the Mosu Member of the Mosolotsane Formation that occurs between the Tlhabala and Ntane Sandstone Formations. Both the Kautse and Mosu Members do not continue eastwards in the Makgaba area according to Stansfield (1973). Stansfield (1973) suggested that this was due to a period of gentle tilting and flexing of the pre-Lebung Group sediments followed by a period of erosion prior to the deposition of the Ntane Sandstone Formation and that this was most pronounced in the east of the area. Hence, the Mosu Sandstone, the Kautse beds and the upper part of the Tlapana Mudstone in the eastern part of the Tlalamabele area were removed by erosion prior the deposition of the Ntane sandstone. The Mosolotsane Formation appears to be absent to the north where the Ntane Sandstone Formation overlies the older Karoo formations unconformable (Smith 1984).

The base of the Lebung Group is marked by an unconformity which, just east of Mosu, comprises a pebble conglomerate up to 25 cm thick with well-rounded clasts up to cobble size composed of sandstone (Stansfield 1973). The base of the Ntane Sandstone has been intruded by dolerite sill.

Green (1965) regarded the Kautse beds as most probably 'Beaufort Series'. Smith (1984) allocated the whole Tlhabala Formation as the Beaufort Group equivalent.

The contact of the Tlhabala Formation, and the overlying Lebung Group, either by the Mosolotsane Formation or the younger Ntane Sandstone Formation, represents a major unconformity separating the 'upper' Karoo from the 'lower' Karoo Supergroup (Smith 1984, Bordy *et al.* 2010). It should also be emphasized that the base-Molteno angular unconformity is well-developed in many of the Karoo basins in south-central Africa (Catuneanu *et al.* 2005).

RESULTS

Field observations

The small hill on which the uppermost occurring tree fossils (T3) are found has grey mudstones at the base and is overlain by medium grained cross-bedded sandstones that are pebbly in places. The fossil site occurs some 3 m above this contact.

The grey mudstones are non-carbonaceous and have some interbedded limestone lenses. The mudstones are

Table 2. Correlation of the Karoo lithostratigraphic units of the main Karoo Basin and the Kalahari Basin in northeast Botswana.

Time scale	Main Karoo basin SA (Catuneanu et al. 2005)		Northeast Botswana (Smith 1984; Johnson et al. 1996)	
	Group	Formation	Group	Formation
Jurassic	Drakensberg	Drakensberg basalt	Stormberg Lava Group	
	Stormberg	Clarens	Lebung	Ntane Sandstone
		Elliot		Mosolotsane (Mosu member)
Triassic		Molteno		
	Beaufort	From Koonap to Burgersdorp	Beaufort equivalent	Tlhabala (Kautse member)
Permian	Ecca	From Prince Albert at the base to Waterford & Fort Brown at the top	Ecca	Tlapana
				Mea Arkose
				Tswane
Late Carboniferous	Dwyka	Elandsvlei	Dwyka	Dukwi

Figure 3. Contact between the Tlhabala Formation and overlying sandstones of the Mosolotsane Formation (**left**) at T11. Note isolated pebbles occur at this contact and the ferruginous nature of the contact. Well-rounded pebbles derived from the base of the Mosolotsane Formation (**right**).

highly weathered and partially covered by scree material. The carbonates are between 0.2 and 0.4 m thick, and are restricted in lateral extent but can be followed for up to 20 m. They contain septarian nodules that can be up to 15 cm in diameter. These are almost round, light grey in colour and are cut by carbonate veins. All around the hill and below the mudstone/sandstone contact septarian nodules are found that have weathered out of the limestones.

The sandstones directly above the mudstones are medium-grained with low angle planar cross-beds. The grains are sub-angular and composed of quartz, feldspar and some micas. Well-rounded small pebbles of mainly vein quartz are present in some of the beds. The sandstones are highly weathered. Palaeo-flow direction from only four readings suggest a flow was to the southeast (144° Mn). At the base of the sandstones is a conglomerate that directly overlies the grey mudstones at sites T3, T11 and between T16 and T19 with an erosional contact (Fig. 3). The conglomerate comprises a single bed of well-rounded medium to large pebbles composed of mainly of quartz-schist and quartzite that have a ferruginized cement along the basal erosional contact (Fig. 3). Directly below the mudstone/sandstone contact at T3 and some 3 m below the fossil tree T3, similar pebbles are found with clasts up to 12 cm in diameter. The clasts are mainly composed of clean and grey quartzite, bedded dark quartzite, quartz-schist, quartz porphery and vein quartz. The clasts are all well-rounded and polished with no obvious percussion marks. Some are facetted and a large component has tabular shapes.

The interpretation is that the mudstones belong to the Kautse Member of the Thlabala Formation based on the lithological descriptions provided by Smith (1984) of the Kautse Member near Mosu. The limestone lenses and the presence of septarian nodules clearly equates these sediments with the Kautse Member. The overlying sandstones with its basal conglomerate is believed to be an easterly extension of the Mosu Member of the Mosolotsane Formation. Both members were not mapped as far east as the Makgaba site but based on the lithological similarities with the descriptions of Stansfield (1973) and Smith (1984) it is suggested that the basal conglomerate, mapped in the field just below the T3 fossil site, is the unconformity between the Kautse Member of the Tlhabala Formation (Beaufort Group) and the Mosu Member of the Mosolotsane Formation (Lebung Group).

The Lebung Group above the basal conglomerate comprises coarse sandstones, grits and conglomerate lenses of up to 10 cm thick that are seen at T11 and T19 (Fig. 5). The small- to medium-sized pebbles are sub-rounded to sub-angular in shape and the clasts within these conglomerates are composed mainly of vein quartz and some chert are found higher up within the Mosolotsane Formation (Fig. 4). The sandstones are cross-bedded and contain vertical 'burrow' structures (?*Scolithos*) on some bedding planes (Fig. 4).

Identical thin bands and pockets of rounded quartz pebbles have been described in sandstones that form the Mosu escarpment some 30 km to the west (Stansfield, 1973). These coarse clastics are therefore correlated with the Mosu Member and it is estimated that this member is about 20 m thick.

The Ntane Sandstone Formation (Fig. 2), based on descriptions by Smith (1984), are more uniform fine-grained and have been mapped from T8 and upwards (Fig. 5). The Ntane sandstones have been intruded by dolerite sills of the Stormberg Lava Group that are seen at T6, T8 and T10. The contact between the sills and the cross-bedded Ntane Sandstone was mapped at T8. The contact between the Ntane Sandstone and Mosolotsane Formations is somewhere between sites T10 and T11 but was not pinpointed due to the extensive scree development.

The fossil trees have therefore been placed at the base of Mosu Sandstone of the Mosolotsane Formation which forms part of the lower Lebung Group and just above the Tlhabala/Mosolotsane unconformity. It can be correlated with the Molteno Formation in South Africa lithostratigraphically (Table 2) (Bordy 2010).

Fossil description

Two samples, 3A (BP/16/1956) and 3B (BP/16/1957), were

Figure 4. Mosolotsane coarse conglomerates (**left**) with mainly quartz pebbles and coarse-grained cross-bedded sandstones with an upper bioturbated (?) zone (**right**) at T19.

both taken from fossil T3. The wood is completely replaced by silica and three petrographic thin sections were cut of each sample along the *x*, *y* and *z* axes.

BP/16/1956 is highly compacted and the tracheids have been compressed. The wood has a zig-zag appearance in transverse section (Fig. 6) but non-compacted tracheids would normally have a rounded to squarish outline and be aligned in more or less straight rows. No growth rings could be detected. In longitudinal section medullary rays are uniseriate and ghosts of bordered pits on the tracheid

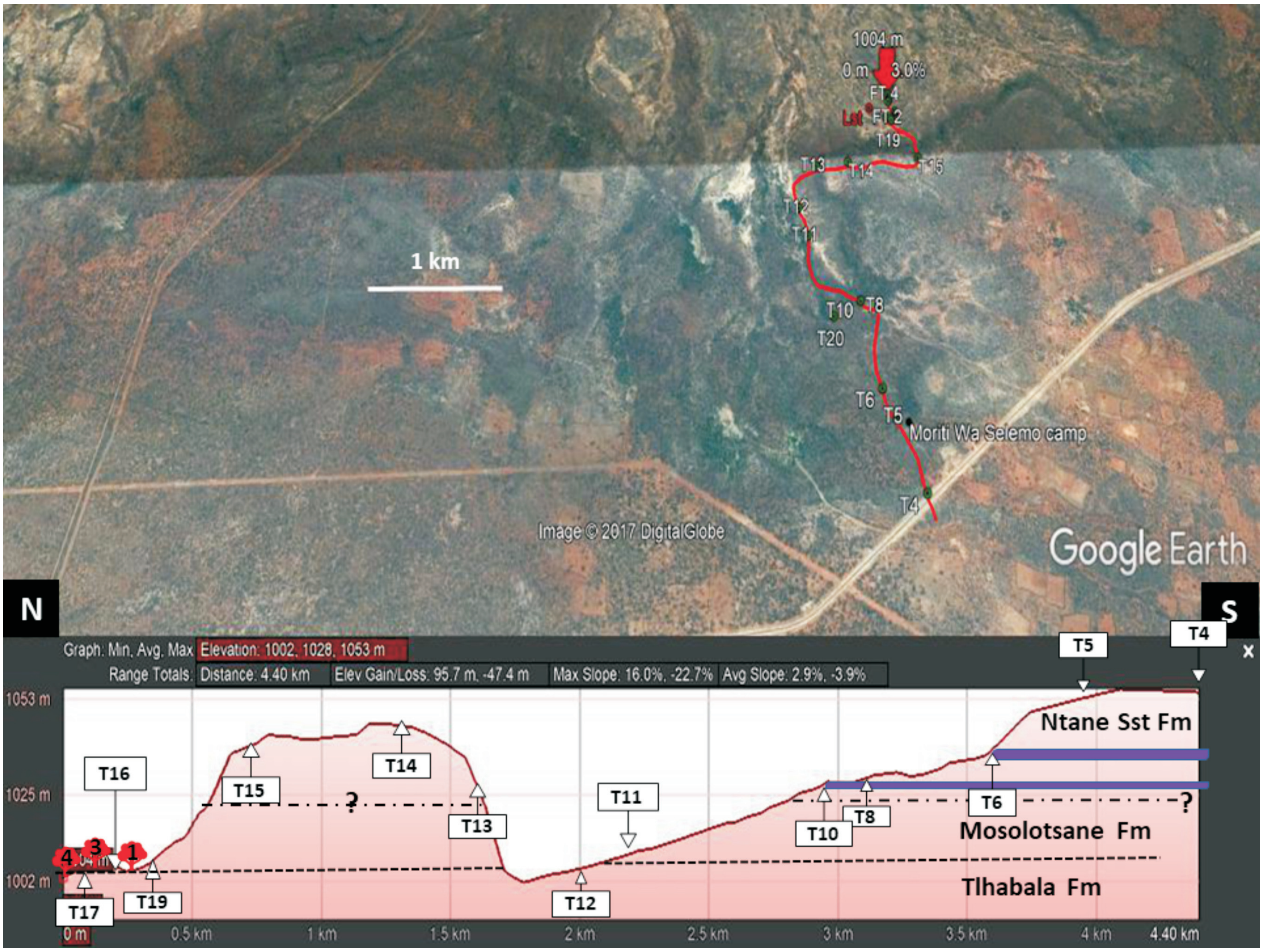

Figure 5. North–south section from the fossil tree site (T1, T3 and T18) to the main road Orapa-Francistown road (T4). The horizontal dashed line on the section marks the unconformity between the Tlhabala Formation and the overlying Mosolotsane Formation. Contact between Mosolotsane and Ntane Sst Formations was not seen. Horizontal purple zones are Karoo dolerite sills *c*. 182 Ma. Approximate positions of fossil trees are shown in red in the section.

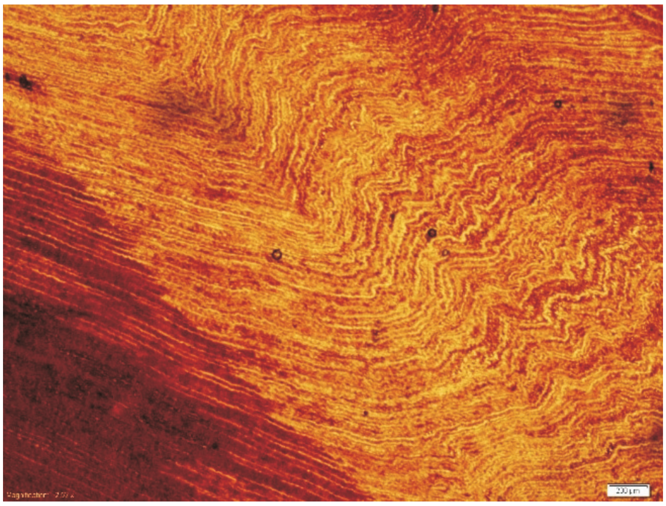

Figure 6. Photomicrograph of a transverse section of sample BP-16-1956.

walls can be seen in a biseriate, compressed, alternate arrangement. No cross-field pits are visible. It is possible that this sample represents a twisted branch or root of the tree.

Sample BP-16-1956 (Fig. 6) is highly compressed but is an *Agathoxylon* sp. Identification to species level was not possible.

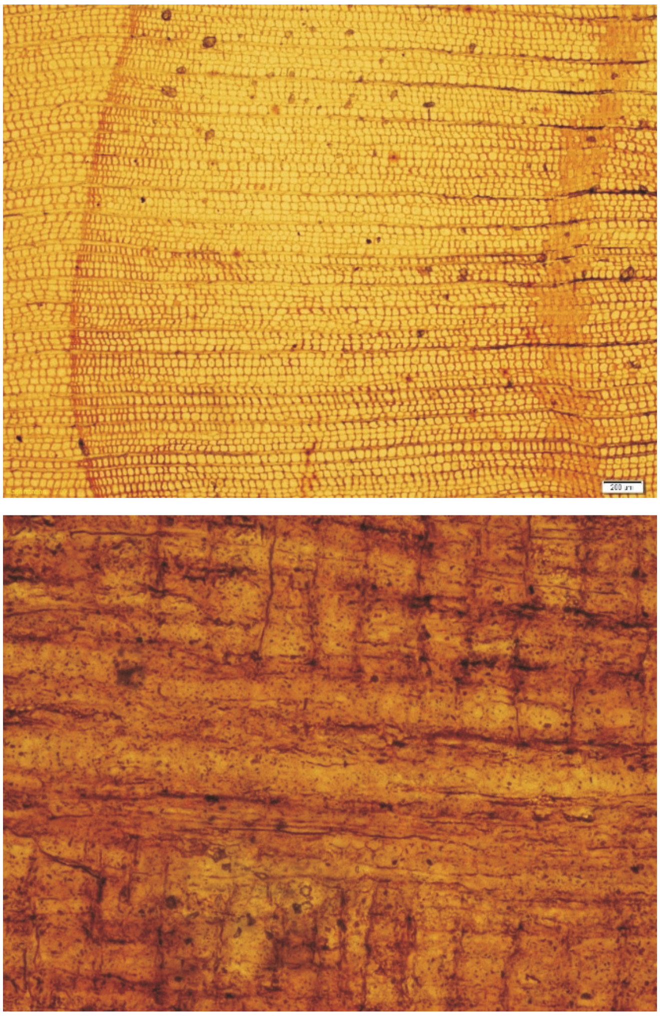

Figure 7. Photomicrographs of sample BP-16-1957. **Top**, a transverse section (ts) showing a growth ring with narrow latewood (thick-walled cells). **Bottom**, BP-16-1957 a radial longitudinal section (rls) with ghosts of biseriate, alternate bordered pits.

Sample BP/16/1957 (Fig. 7) from the same tree is much better preserved and not distorted. It has a clear transverse section with regular tracheids, narrow latewood and also some false growth rings. In longitudinal section rays are uniseriate and the same ghosts of biseriate, alternate tracheid pits can be seen but not clearly (Fig. 7). Based on the arrangement of tracheid pits, i.e. araucarian, it is clear that sample BP-16-1957 is *Agathoxylon*, and most likely *Agathoxylon africanum* because the tracheid pits are biseriate. This species has a Permian to Triassic time range in southern Africa (Bamford 1999).

DISCUSSION

Other samples of Permian-Triassic woods have been recorded from Botswana but their taxonomy needs to be updated. From the Boteti River near Motopi Village, three samples were described (Bamford, 1997) but they differ from this sample. The wood from the southwestern edge of the Sua pan, near Tshaitshe (Bamford 1997) was described as *Dadoxylon parenchymosum* but this genus is invalid (Philippe 1993; Bamford & Philippe 2000; Philippe & Bamford 2008; Rossler *et al.* 2014) and because of its mixed tracheid pitting should be called something else, for example *Metapodocarpoxylon* or *Brachyoxylon*. There are a number of options but without cross-field pits it is not possible to select the genus.

As the first record of woods of Molteno age in Botswana, the occurrence of *Agathoxylon* sp. indicates that further research should be done to find other elements of this flora, for example the iconic *Dicroidium* leaf flora of the upper Karoo sequence. This would improve the record of fossils in southern Africa but also has implications for understanding the stratigraphy (potentially for economic applications) and past climate, biodiversity and local environmental settings. The Mosolotsane Formation is the place to begin to look for more woods and other plants in Botswana.

CONCLUSION

The fossil trees, found on the southern edge of Sua Pan, have been sourced from the base of the Mosu Member sandstones which forms the lower Mosolotsane Formation. This puts it somewhere at the base of the Molteno equivalent above the regional unconformity. The fossil wood, which is the first published record of *Agathoxylon africanum* in Botswana, from a biostratigraphic point of view, has been placed in the Triassic. Although the age range of the species is longer, lithostratigraphically the age of the Makgaba fossils would be constrained to between 240 and 250 Ma.

Andries Kruger of the Moriti wa Selemo camp is thanked for his hospitality during the visits to the area and Prosper Bande (Evolutionary Studies Institute, University of the Witwatersrand) for making the petrographic slides of the silicified wood. The authors also wish to thank Drs Roger Smith and Bastien Linol for their input and suggestions which has greatly improved this manuscript.

REFERENCES

BORDY, E.M., SEGWABE, T. & MAKUKE, B. 2010. Sedimentology of the Upper Triassic-Lower Jurassic (?) Mosolotsane Formation (Karoo Supergroup), Kalahari Karoo Basin, Botswana. *Journal of African Earth Sciences* **58**, 127–140.

BAMFORD, M.K. 1999. Permo-Triassic fossil woods from the South African Karoo Basin. *Palaeontologia africana* **35**, 25–40.
BAMFORD, M.K. 1997. Fossil wood from the Boteti River and Tshaitshe, Botswana. *Botswana Notes and Records* **29**, 1–8.
BAMFORD, M.K. 2016. Fossil wood and leaves from Mike de Wit August 2017. Note for the record, 1 p.
BAMFORD, M.K. & PHILIPPE, M. 2001. Jurassic – Early Cretaceous Gondwanan homoxylous woods: a nomenclatural revision of the genera with taxonomic notes. *Review of Palaeobotany and Palynology* **113**, 287–297.
CATUNEANU, O., WOPFNER, H., ERIKSSON, P.G., CAIRNCROSS, B., RUBIDGE, B.S., SMITH, R.M.H. & HANCOX, P.J. 2005. The Karoo basins of south-central Africa. *Journal of African Earth Sciences* **43**, 211–253.
GREEN, D. 1965. The Kautse Beds and the sandstones of the Kedia area. Geological Survey of Botswana, unpublished report.
JOHNSON, M.R., van VUUREN, C.J., HEGENBERGER, W.F., KEY, R. & SHOKO, U. 1996. Stratigraphy of the Karoo Supergroup in southern Africa: an overview. *Journal of African Earth Sciences* **23**, 3–15.
PHILIPPE, M. & BAMFORD, M.K. 2008. A key to morphogenera used for Mesozoic conifer-like woods. *Review of Palaeobotany and Palynology* **148**, 184–207.
RÖßLER, R., PHILIPPE, M., van KONIJNENBURG-van CITTERT, J.H.A., McLOUGHLIN, S., SAKALA, J., ZIJLSTRA, G. *et al.* 2014. Which name(s) should be used for *Araucaria*-like fossil wood? – Results of a poll. *Taxon* **63**(1), 177–184.
SMITH, R.A. 1984. The Lithostratigraphy of the Karoo Supergroup in Botswana. *Geological Survey of Botswana, Bulletin* **26**, 239 pp.
STANSFIELD, G. 1973. The geology of the area around Dukwe and Tlalamabele, Central Districts, Botswana. *Geological Survey of Botswana, District Memoir* **1**, 74 pp.