Fossil Freshwater Molluscs from Simanya in the Kalahari System, Northern Namibia

Helke Mocke[1], Alma Nankela[2], Martin Pickford[3], Brigitte Senut[3] and Loïc Ségalen[3]

1. Geological Survey of Namibia, 1, Aviation Road, Windhoek.
(*e-mail: <Helke.Mocke@mme.gov.na>*)
2. National Heritage Council of Namibia, Windhoek.
3. Sorbonne Universités (CR2P, UMR 7207 du CNRS, Département Histoire de la Terre, Muséum National d'Histoire Naturelle et Université Pierre et Marie Curie) case postale 38, 57 rue Cuvier, 75005 Paris.
(*e-mail: <pickford@mnhn.fr>*)

Abstract: Fossil freshwater molluscan shells and steinkerns have been found at Simanya, on the Southwestern Bank of the Cubango River in Northern Namibia. The occurrence of fossils resembles those reported from other sites in the « Grès Polymorphes » subunit of the Kalahari System of Central Africa. The aim of this paper is to describe and interpret the Simanya fossils and to discuss their stratigraphic and palaeoenvironmental contexts. The silicified deposits (chert, chalcedony) in which the snails occur were extensively used by prehistoric peoples for manufacturing of stone tools.

Key Words: Chert; Chalcedony; Grès Polymorphes; Plio-Pleistocene; Gastropods; Fossils; Namibia.

To cite this paper: Mocke, H. Nankela, A. Pickford, M. Senut, B. & Ségalen, L. 2016. Fossil Freshwater Molluscs from Simanya in the Kalahari System, Northern Namibia. *Communications of the Geological Survey of Namibia*, **17**, 66-84.

Submitted November 2015

Introduction

In 2013, the discovery of fossil gastropods at Simanya River Lodge on the southwestern bank of the Cubango River, was reported to the Geological Survey of Namibia by the owners of the lodge.

A visit to the site by HM and AN resulted in the collection of additional fossils which included ampullariids, pomatiopsids and planorbids as well as small fragments of silicified wood.

The aim of this note is to identify and interpret the snail fossils from Simanya and to discuss their importance within the context of the fossil record of the Grès Polymorphes of the Kalahari System.

Geological Setting

The Simanya silicified deposits occur on the southwestern flank of the Kavango (Cubango) River at Simanya River Lodge (S 17°32'27.6'': E 18°32'00.1'') at an altitude of 1113 m (GPS set to WGS 84) (Fig. 1). The locality is just outside the eastern flank of the Cubango Megafan (Miller *et al*. 2010) and as such, the sediments underlying the silicified horizon (1 - 1.5 m thick) comprise poorly consolidated fluviatile pale grey-yellow sandy silts and sandstones with millimetric quartz pebbles, over 20 metres thick (exposed down to river level) and are overlain by 1-2 metres of unconsolidated red sands (Fig. 2).

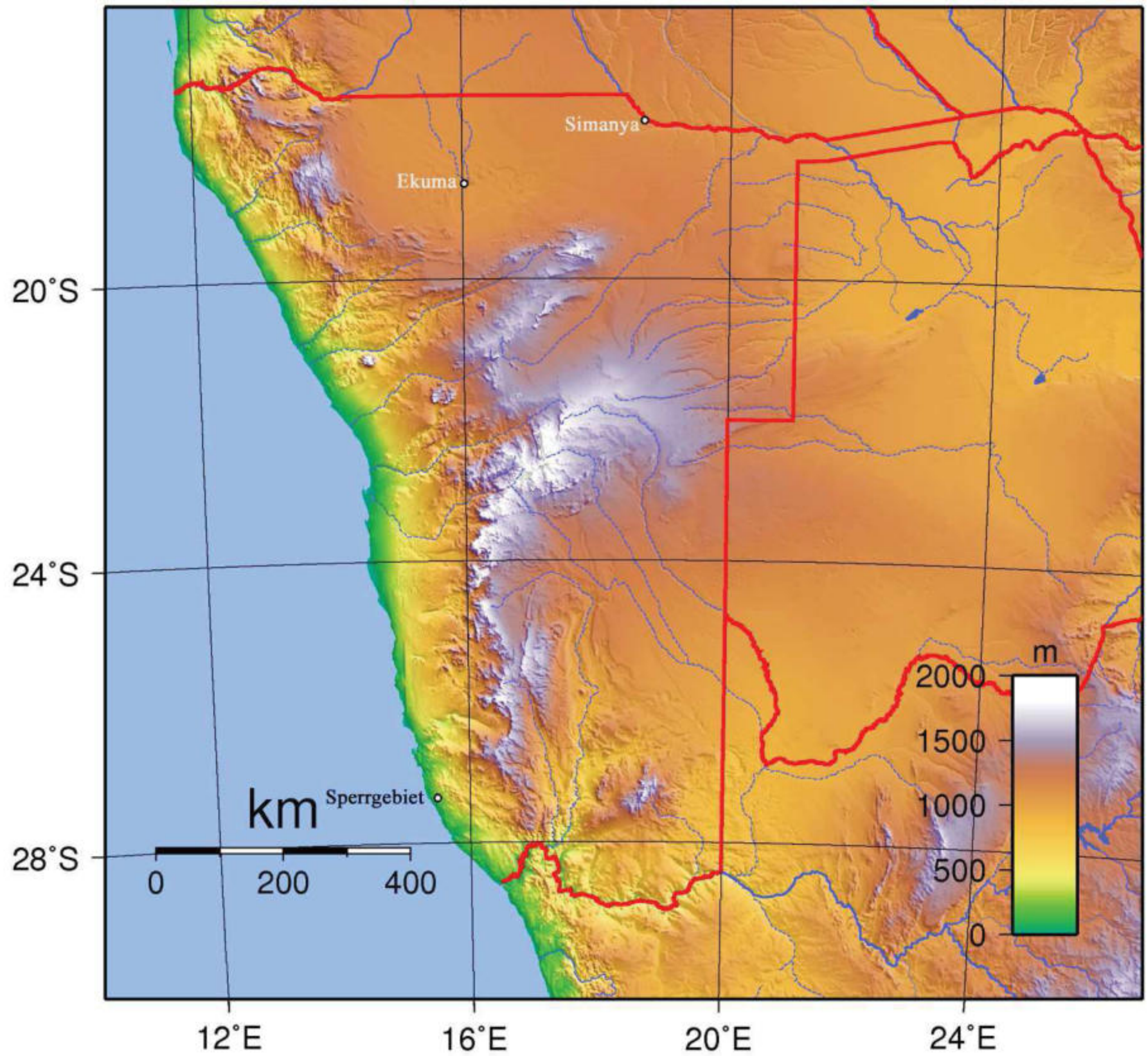

Figure 1. Relief map of Namibia depicting occurrences of silicified rock rich in fossil freshwater molluscs at Simanya, Ekuma and the Sperrgebiet.

The silicified deposits at Simanya occur principally as loose blocks in the slopes leading down to river level (Fig. 3) where masses of cobbles have accumulated in certain places in the shallows (1090 metres above sea level) (often aligned by local inhabitants to make fish traps) (Fig. 4). Limited outcrops occur *in situ* beneath the crest of the valley where its southwestern slopes fade out upwards into the Kalahari Plains to the southwest.

In the broad valley bottom of the Cubango River, there are younger silts and marls (Late Pleistocene to Recent) which are also fossiliferous (snails, plant remains) but which show no signs of silicification. These younger deposits correspond, for the most part, to floodplain silts and marls overlain by, or comprising eutric fluvisols (Jones *et al*. 2013). The pale grey indurated marly beds are exploited locally for brick-making as they are easy to excavate and to cut to size with machetes.

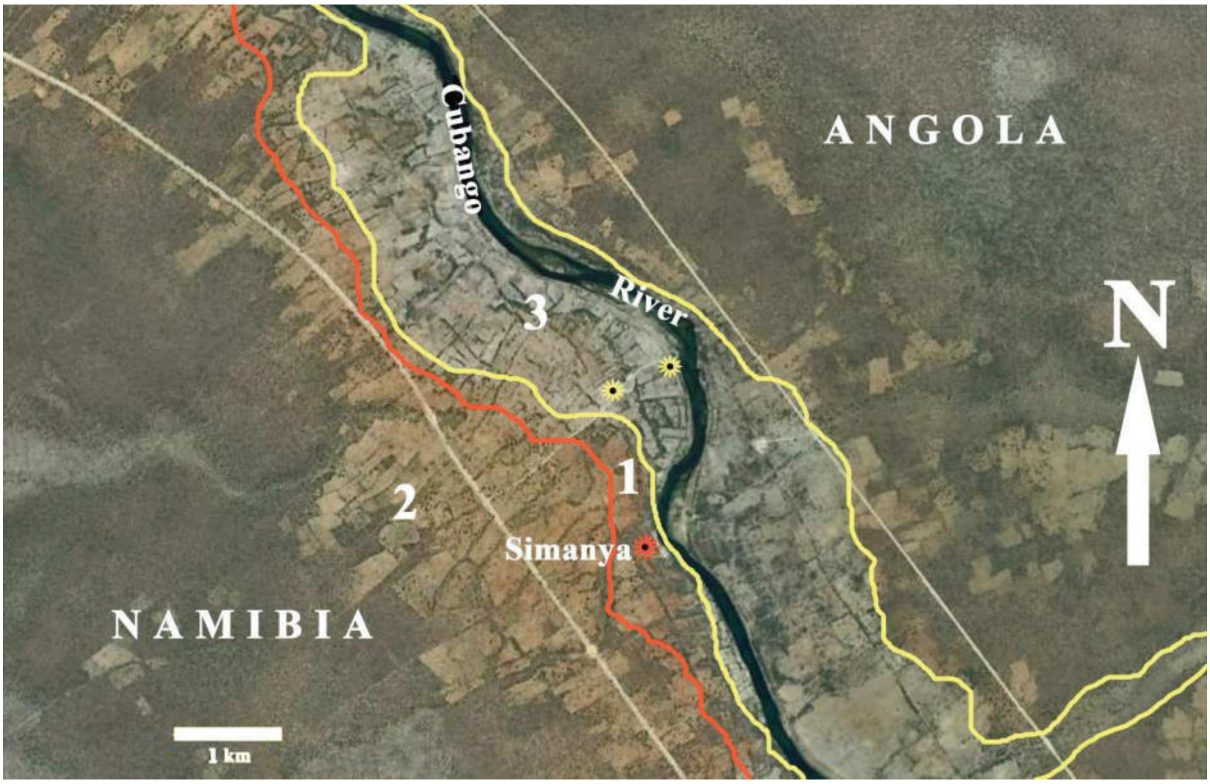

Figure 2. Local geology of the region around Simanya River Lodge. 1 - West Bank of the Cubango River with poor exposures of fluvio-paludal sands and silts, silicified just beneath the top of the slope; 2 - Kalahari Red Sands and interdune vlei silts (which accumulated in small endorheic depressions and shallow valleys); 3 - Floodplain deposits of the Cubango River dominated by indurated marls and eutric fluvisols. Orange star: richly fossiliferous silicified sand and marl (chert, chalcedony) beneath the Kalahari Red Sands, Yellow stars: fossiliferous moderately indurated marl of the Cubango floodplain deposits (Map modified from Google Earth).

Examination of the Simanya silicified deposits under the hand lens reveals that the cherty fractions are comprised of fine sand and marl with occasional well-rounded millimetric quartz pebbles, all intensively silicified to produce a dark brown, homogeneous flint-like rock, often with a porous surface.

The chalcedonic deposits are pale yellow to light brown and are less densely silicified, and some of them appear to correspond to silicified marls (and eutric fluvisols). Both rock types are fossiliferous and contain predominantly gastropods, but also ostracods, plant rootlets and rare small pieces of silicified wood.

Material and methods

The fossils described herein are curated at the Geological Survey of Namibia, Windhoek, under the abbreviation « Sim » followed by the catalogue number (Table 1). They were measured with sliding calipers to the nearest tenth of a mm. Images were captured with a Sony Cybershot Camera and enhanced using Photoshop Elements 03.

Comparisons were made with extant gastropods from Africa (Brown, 1980; Connolly, 1939) and fossils from the Grès Polymorphes (Leriche, 1928, 1933; Mouta & Dartevelle, 1952; Newton, 1920; Polinard, 1933b). Nomenclature of shell parts is based on West *et al*. 2003.

Due to the limitations of the preserved parts of the shells (half the specimens are steinkerns) it would be illusory to pretend to be able to identify all the specimens to the species level. Therefore, we describe the specimens and provide tentative identifications to species where the evidence warrants it. Otherwise we remain at the heirarchical level of the genus.

Figure 3. Blocks of silicified sands and marls at Simanya River Lodge, Namibia, at shallow depths near the southwestern edge of the Cubango Valley. Note the grass-rich Miombo Woodland vegetation and the thin cover of red sand. The site yields abundant fossil freshwater snails.

Figure 4. Concentrations of blocks of silicified sediment in the bed of the Cubango River, arranged by local inhabitants into artisanal fish traps. Note the pale silts and eutric fluvisol forming the bank of the river (on the right of the image) and the Simanya River Lodge in the background.

Table 1. Catalogue of fossil specimens and stone tools from Simanya, Northern Namibia (measurements are in mm).

Locality	**Catalogue**	**Identification**	**Description**	**Breadth**	**Height**
Simanya	1	*Pila*	steinkern	55.5	52.9
Simanya	2	*Tomichia*	section	1.3	
Simanya	3	*Bulinus*	shell	6.7	
Simanya	4	*Pila*	shell fragment		
Simanya	5	*Pila*	shell		
Simanya	6	*Pila*	shell fragment & operculum		
Simanya	7	*Pila*	shell		
Simanya	8	*Pila*	fragment		
Simanya	9	*Pila*	steinkern	38.4	
Simanya	10	*Pila*	steinkern	32.0	
Simanya	11	*Pila*	mould of spire	27.2	
Simanya	12	*Pila*	shell		
Simanya	13	*Pila*	shell		
Simanya	14	*Pila*	shell		
Simanya	15	*Pila*	shell	30+	
Simanya	16	*Pila*	shell		
Simanya	17	*Pila*	mould		
Simanya	18	*Pila*	shell	35.5	
Simanya	19	*Pila*	mould		
Simanya	20	*Ceratophallus*	shell	2.7	
Simanya	21	*Bulinus*	shell	4.8	
Simanya	22	*Bulinus* + ostracod	shell		
Simanya	23	Various snails	shells		
Simanya	24	*Bulinus*	shell	4.2	
Simanya	25	Unidentified dextral snail	shell	1.8	
Simanya	26	*Ceratophallus*	shell	2.1	
Simanya	27	*Ceratophallus*	shell		
Simanya	28	*Bulinus*	shell	2.7	
Simanya	29	*Bulinus*	shell	3.2	
Simanya	30	*Bulinus*	shell		
Simanya	31	*Bulinus*	shell	4.5	
Simanya	32	*Bulinus*	shell	5.0	
Simanya	33	*Bulinus*	shell		
Simanya	34	*Ceratophallus*	shell		
Simanya	35	*Bulinus*	shell		
Simanya	36	*Bulinus*	shells	3.5, 2.4	
Simanya	37	*Bulinus*	shell		
Simanya	38	*Ceratophallus*	shell	2.7	
Simanya	39	*Ceratophallus*	impression	2.1	
Simanya	40	*Bulinus*	shell	4.5	
Simanya	41	*Bulinus* elongate form	shell	1.3	
Simanya	42	Various snails	shells		

Simanya	43	Various snails	shells	
Simanya	44	*Pila + Ceratophallus*	shell	
Simanya	45	*Bulinus*	shell	
Simanya	46	*Ceratophallus*	shell	3.4
Simanya	47	Plant	wood	
Simanya	48	*Ceratophallus*	shell	1.7
Simanya	49	*Ceratophallus*	shell	1.8
Simanya	50	*Bulinus*	shell	2.2
Simanya	51	*Bulinus*	section	2.9
Simanya	52	*Bulinus*	spire	2.9
Simanya	53	*Bulinus*	shell	
Simanya	54	Various snails	sections	
Simanya	55	*Ceratophallus*	impression	
Simanya	56	Various snails	shells	
Simanya	57	*Bulinus*	shell	1.7
Simanya	58	*Bulinus*	shell	2.7
Simanya	59	*Bulinus*	mould	
Simanya	60	Snail	shell	
Simanya	61	Snail	sections	
Simanya	62	*Ceratophallus*	small shell	
Simanya	63	*Tomichia, Ceratophallus, Bulinus*	shells	1.8
Simanya	64	*Bulinus*	shell	
Simanya	65	Plant	roots	
Simanya	66	Snail	mould	
Simanya	67	Ostracod?	shell	
Simanya	68	*Bulinus*	shell	
Simanya	69	Chert	Tool	
Simanya	70	Chert	Tool	
Simanya	71	Chert	Tool	
Simanya	72	Chert	Flake	
Simanya	73	Chert	Flake	
Simanya	74	Chert	Flake	
Simanya	75	Chert	Flake	
Simanya	76	Chert	Flake	
Simanya	77	Chert	Flake	
Simanya	78	Chert	Flake	
Simanya	79	Chert	Flake	
Simanya	80	Chert	Flake	
Simanya	81	Chert	Flake	
Simanya	82	Chert	Flake	
Simanya	83	Chert	Flake	
Simanya	84	Chert	Chopper	
Simanya	85	*Ceratophallus*	impression	2.0
Simanya	86	*Pila*	impression	

Systematic organisation

The descriptions of the Simanya fossil snails follow the systematic scheme presented by Brown (1980) with modifications following West *et al*. (2003).

Table 2. Systematic schema of fossils described in this paper.

Class Gastropoda Cuvier, 1798

Family Ampullariidae Gray, 1824

Genus *Pila* Röding, 1798

Family Pomatiopsidae Stimpson, 1865

Subfamily Pomatiopsinae Stimpson, 1865

Genus *Tomichia* Benson, 1851

Family Planorbidae Rafinesque, 1815

Subfamily Planorbinae Rafinesque, 1815

Genus *Ceratophallus* Brown & Mandahl-Barth, 1973

Subfamily Bulininae Oken, 1815

Genus *Bulinus* Müller, 1791

Descriptions of Simanya fossil Gastropoda

Genus *Pila* Röding, 1798

Several medium to large dextral globose shells from Simanya with depressed conic apices are confidently attributed to the genus *Pila*, and probably to the species *wernei* (Fig. 5, A-E).

The shells have shouldered whorls, a relatively low spire and the aperture is appreciably taller than its breadth, as in the species *Pila wernei* in contrast to the broader aperture of *Pila ovata*. The umbilicus is open but not very broad.

The shells range in diameter from 35.5 to 55 mm. The tallest individual has a height of 52.9 mm.

Genus *Tomichia* Benson, 1851

Two small dextral elongate conic shells from Simanya are close in dimensions and shell morphology to extant *Tomichia*. The specimens are 1.3 mm and 1.8 mm in width.

The sutures are impressed, the whorls rounded and the shell surface smooth (Fig. 6, G, H). The Simanya specimen is similar in shell features (dimensions, whorl number, ratio of breadth to height, degree of impression of the suture) to several species of *Tomichia* such as *T. lirata*.

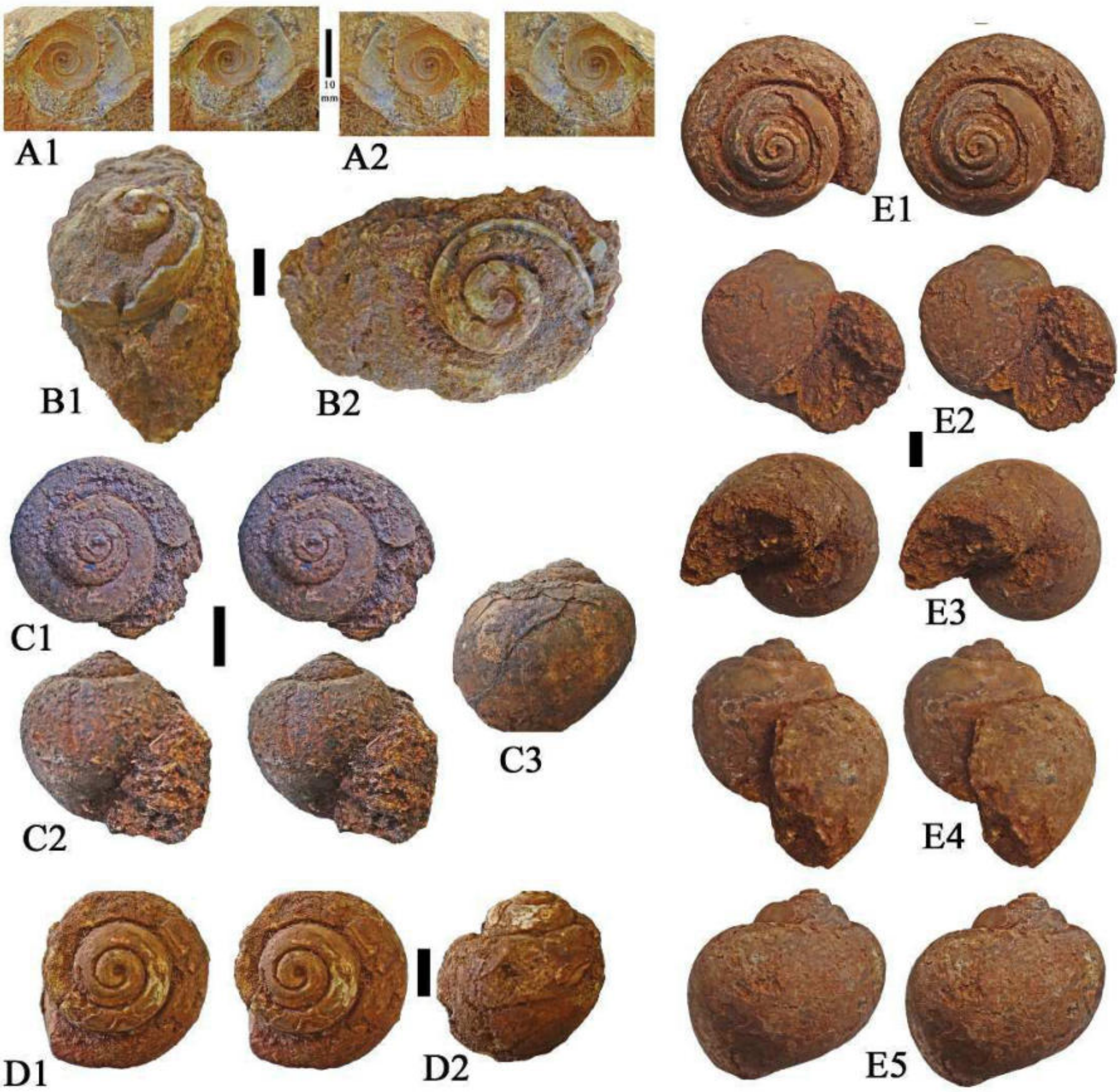

Figure 5. Shells and steinkerns of *Pila* cf *wernei* from Simanya, Northern Namibia. A) Sim 11, impression of apex of shell (A1 - stereo image of impression, A2 - stereo images reversed to produce positive relief image of the apex); B) Sim 18, damaged shell in chert nodule (B1 - lateral view, B2 - apical view); C) Sim 10, steinkern (C1 - stereo apical view, C2 - stereo apertural view, C3 - lateral view); D) Sim 9, steinkern (D1 - stereo apical view, D2 - lateral view); E) Sim 1, partly shell, partly steinkern (stereo images of E1 - apical view, E2 - apertural view, E3 - basal view, E4 - lateral view, E5 - back view) (scales - 10 mm).

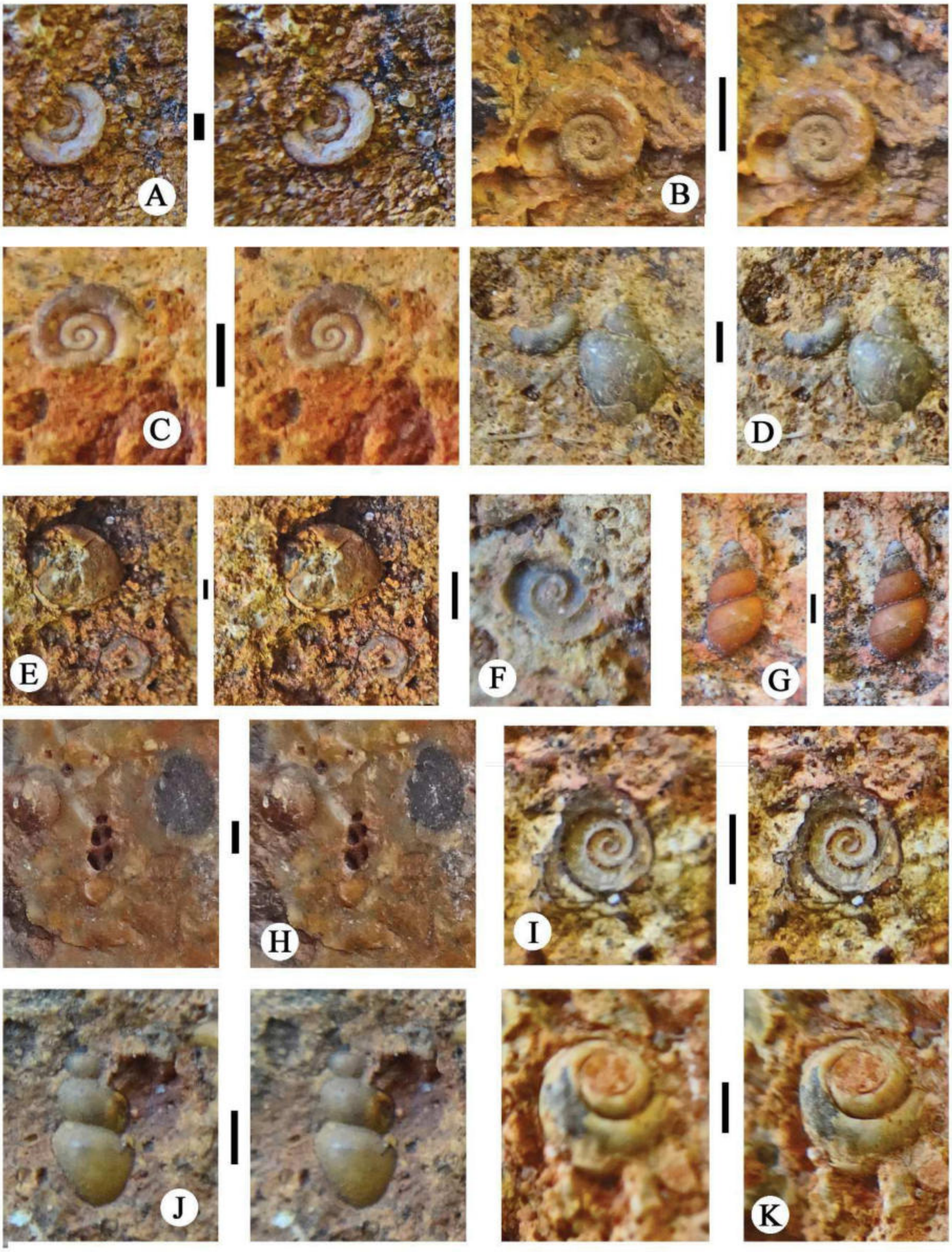

Figure 6. Fossil molluscs from Simanya, Northern Namibia. A) Sim 46, *Ceratophallus*, stereo image; B) Sim 48, *Ceratophallus* stereo image; C) Sim 49, *Ceratophallus* stereo image; D) Sim 50, associated shells of planorbid and *Bulinus*, stereo images; E) Sim 40, planorbid and *Bulinus* shells, stereo image; F) Sim 39, impression of planorbid shell in chert; G) Sim 63, *Tomichia*, stereo image; H) Sim 2, cross section of *Tomichia*, stereo pair; I) Sim 57, *Bulinus* apex in stereo view; J) Sim 41, elongate *Bulinus*, stereo image of back of shell; K) Sim 62, *Bulinus* steinkern lacking its apex, stereo image (scales: 1 mm).

Genus *Ceratophallus* Brown & Mandahl-Barth, 1973

Planorbid shells are quite common at Simanya. They possess a rounded periphery, an extremely broad umbilicus and sunken spire (Fig. 6, A, B, C, F). Attribution to *Afrogyrus*, *Armiger*, *Gyraulus*, *Lentorbis*, *Segmentorbis*, *Biomphalaria*, *Helisoma* and *Indoplanorbis* can be ruled out on the basis of the breadth to height ratio of the shells, or on the absence of angulation in the body whorl, or on the breadth of the umbilicus, or on the absence of external shell ornamentation. The closest resemblances of the Simanya shells are to *Planorbis* and *Ceratophallus*, but the more rounded whorl without a basal angulation shifts the balance towards *Ceratophallus*. One of the specimens in particular (Fig. 6a) resembles *Ceratophallus natalensis*.

Genus *Bulinus* Müller, 1791

Small sinistral shells are common at Simanya, and they show a diversity of shell shapes, indicating the presence of at least three species.

The first form has a low spire like *Bulinus angolensis* (Fig. 6, E, I, K; Fig. 7, A), the second has a taller spire with a pointed apex, like *Bulinus tropicus* (Fig. 6, D; Fig. 7, B, D, E, F) while the third is elongated, somewhat like the species *Bulinus scalaris* (Fig. 6, J).

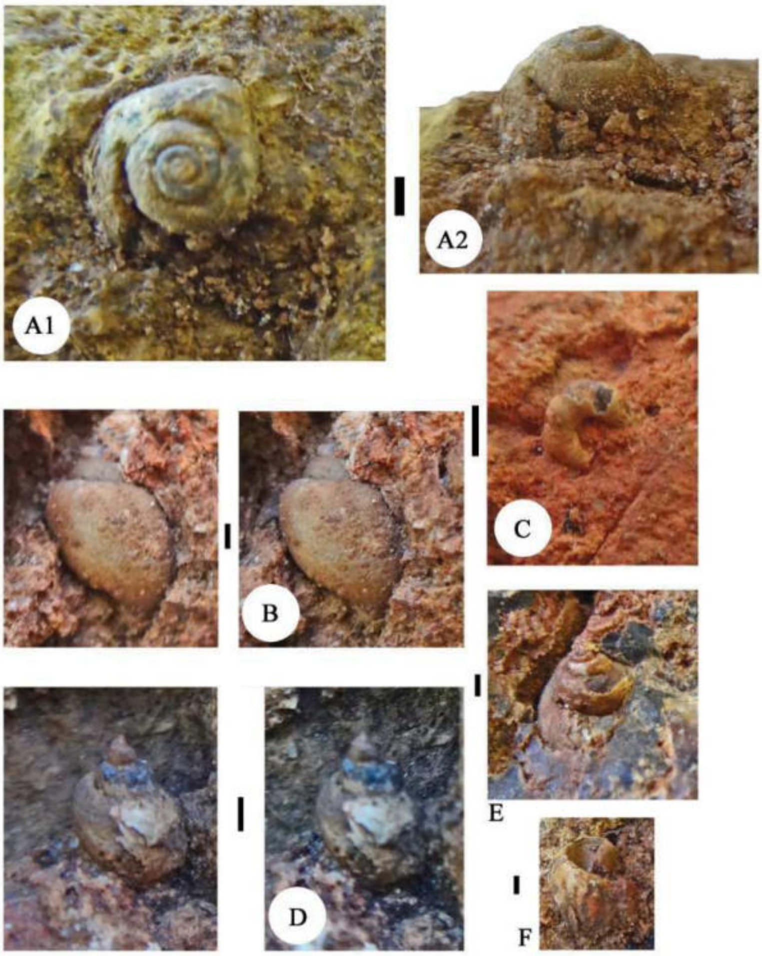

Figure 7. Silicified gastropods in chert and chalcedony from Simanya, Northern Namibia. A) Sim 21, apex of *Bulinus*, A1 - apical and A2 - apertural views; B) Sim 33, *Bulinus*, stereo view of back of shell; C) Sim 25, unidentified dextral shell, basal view; D) Sim 36, *Bulinus*, stereo view of back of shell; E) Sim 31, *Bulinus* shell in chert; F) Sim 32, *Bulinus* steinkern lacking the apex (scales: 1 mm).

Genus indet.

There is a small dextral shell from Simanya (Sim 25) with an open umbilicus, almost circular body whorl and clear but irregular growth lines or rugosities (Fig. 7, C). The apex and the upper half of the aperture are not visible which makes it difficult to identify, but it does not resemble any of the other material from the site. There are several African freshwater snails which show the same degree of opening of the umbilicus and the rounded body whorl, including *Valvata*, some species of *Gabiella* and *Funduella*. More complete material is required to determine the affinities of this snail.

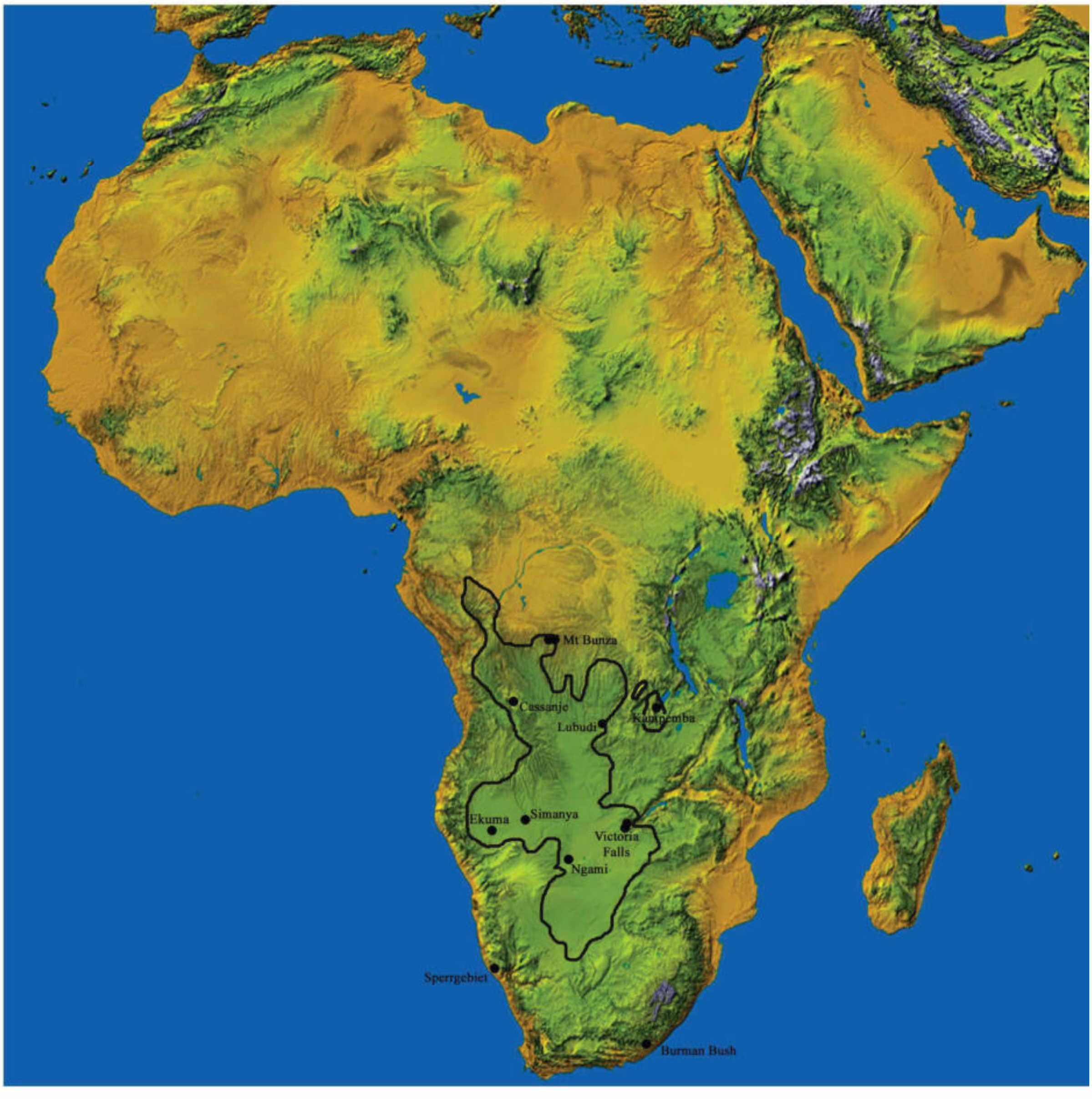

Figure 8. Relief Map of Africa showing the approximate extent of the Kalahari System (inside the black lines) and the occurrence of silicified freshwater molluscs (black dots) in the sub-equatorial half of the continent. Extent of the Kalahari System is modified from Cahen & Lepersonne, 1952. (Position of Burman Bush is after Frankel, 1964, and Ngami is after Shaw & Thomas, 1988, Thomas & Shaw, 1991, and Shaw, 1985).

The Grès Polymorphes

The fossil freshwater snails from Simanya occur in silicified fine sand and marl, which can be described as chert (for the dense, dark brown varieties) and chalcedony (for the less dense, paler deposits). In the past, similar deposits which occur in DR Congo, Angola and Zimbabwe, were grouped into the Grès Polymorphes subunit of the Kalahari System (Polinard, 1932; Leriche, 1932; Mouta, 1954; Mouta & O'Donnell, 1937) (Fig. 8).

These strata are in part homonymous with the Kalahari Group of the Owambo Basin as defined by Miller *et al*. (2010). According to Mouta (1954) the Kalahari System comprises the Kamina Stage at the base (known only in the DR Congo), followed by the Grès Polymorphes in the middle, and Red Sandy Deposits (limons sableux ocres) at the top (Anonymous, 1947) which are widespread throughout Congo and Angola, extending as far east as the Victoria Falls, Zimbabwe, and as far south as northern Namibia and Botswana. Through much of Angola, the Red Sandy Deposits are hundreds of metres thick.

Veatch (1935) proposed the following succession for the Post-Karroo rocks of the Kasai-Lunda region:-

Terrace Gravels and Sands - Pleistocene to Recent
Plateau Gravels and Sands - Late Pliocene to Early Pleistocene
High Plateau Sands - Miocene
Generally silicified sands, chalcedonic quartzite, with freshwater fossils - Oligocene
Conglomerates - Oligocene

He recognised two geomorphological surfaces (peneplains); the so-called « Miocene Peneplain » which formed later than the sands of the high plateaux, and the « End-Tertiary Peneplain » which formed later than the Plateau Gravels and Sands. Lepersonne (1945) and Cahen & Lepersonne (1952) agreed in general with these stratigraphic and geomorphological interpretations and extended them from the Congo Basin southwards to South Africa, although they noted that there were localised differences from the overall scheme.

Gastropods from the Grès Polymorphes

Studies of gastropods from the Grès Polymorphes were mostly done during the first half of the 20th Century. The nomenclature of gastropods has evolved in the meantime, with the creation of new genera, such as *Ceratophallus* Brown & Mandahl-Barth, 1973. The fossils described in these pioneer papers need to be re-examined, because it is clear that authors were employing the genus names *Bulinus* and *Planorbis*, for example, in rather different ways than they would be used today. In the following discussion, the original names are recorded as published.

At Mount Bunza (DR Congo - NE Angola) the fossiliferous chalcedony overlies Karroo strata (Leriche, 1928; Maufe, 1929a, 1929b). Leriche (1928) described *Planorbis* sp. and *Physa Parmentieri* (sic) associated with *Chara Rauwi* (sic) and ostracods (*Cypris Farnhami* (sic). Leriche (1925, 1928) concluded that, on the basis of the presence of *Bulinus* and *Planorbis*, the oldest that the Mount Bunza fossils could be is Upper Jurassic, but such an estimate was quickly challenged by Polinard (1933a, 1933b, 1933c) who thought they were much more recent. Mouta (1954) wrote that the fossiliferous «Grès Polymorphes» or «Chalcedonic Quartzites» repose upon an upper Cretaceous surface (the Gondwana Surface of King, 1951) whereas the Kalahari System covers a younger erosion surface, the African Surface of King (1949, 1951). For Mouta (1954) there was a third phase of erosion resulting in the End-Tertiary Surface, which is unconformably overlain by reworked Kalahari sand and gravel deposits and even by much younger fossiliferous silicified formations (Pleistocene).

Newton (1920) listed *Viviparus* and *Hydrobia* in the Chalcedony of Southern Rhodesia (Zimbabwe). Following this lead, Maufe (1929b) listed several gastropod genera from the silicified deposits of the Zambezi Valley (27°- 28°30' E : 19° S). *Viviparus* (*Paludina*), *Hydrobia* («*Paludestrina*»), *Melania* (doubtful), *Limnaea* and *Isodora* (a junior synonym of *Bulinus*) which are accompanied by the charophyte *Chara*. Leriche (1928) considered the Zambezi chalcedony to be a silicified limestone.

Polinard (1933b) described the freshwater fauna from chalcedony found near Lubudi, Katanga, DR Congo. Accompanying ostracods and charophyte gyrogonites, there was a low diversity of gastropods, *Planorbis Fontainasi* (sic), *Bulinus* (*Pyrgophysa*) *Cayeni* (sic), and *Bulinus* (*Pyrgophysa*) sp. He concluded that the Lubudi fauna was close to that of Mont Bunza described by Leriche (1928) despite the different names given to the fossils. He deduced that the Lubudi fossils could be of any age between Jurassic and Quaternary.

Leriche (1933, 1938) recorded a suite of snails associated with charophytes from partly silicified limestones in the valley of the Kampemba (eastern edge of the Kundelungu Plateau - see also Brien, 1921): *Physopsis africana* var. *didieri*, *Limnaea* (sic) cf. *africana*, *Limnaea* (sic) sp. and *Planorbis* sp. On the basis of these identifications, he estimated an Upper Pliocene to Pleistocene age for the occurrence.

Dartevelle (in Mouta & Dartevelle, 1952) identified a variety of snails from silicified deposits (Chalcedony) in the « Grès Polymorphes » at several sites near Cassanje (Malanje, Angola) associated with charophytes and ostracods. There were *Lymnaea* of the *Lymnaea* (*Radix*) *natalensis* group, three forms of *Biomphalaria* (groups *sudanicus*, *choanomphalus* and *adowensis*), *Anisus*, four forms of *Bulinus* (*Bulinus* (*Bulinus*) sp. *Bulinus* (*Pyrgophysa*) cfr *cristalinus*, *Bulinus* (*Pyrgophysa*) cfr *forskali* and *Bulinus* (*Parabythinia*) sp?), Ancylidae sp?, and two forms of *Pila* (*Pila wernei* and *Pila* sp.). There were also questionable remains attributed to a streptaxid land snail and a bivalve, *Caelatura*. Despite the difficulty of interpreting the fossils from Cassanje, due to their fragmentary and poorly preserved condition, Mouta & Dartevelle (1952) were inclined to correlate them to the Pleistocene (probably Middle Pleistocene) on account of the fact that none of the taxa are known from the Early Tertiary, and all of them occur in Africa at the present day. Leriche (1938) reiterated that these deposits are rich in shells of *Pila* (*Ampullaria*).

In brief, the ages of the various stratigraphic units which comprise the Kalahari System remained uncertain during the 20th Century, just as they do today. Rocks attributed to this unit span the vast time period from post-Karroo to Recent. Pertinent to understanding the complexity of the situation are fossil freshwater molluscs from Etosha (the gastropod *Bellamya* and mutelids of middle Pliocene age in silicified sands of the Ekuma Delta Member: Pickford *et al*. 2014, 2016; Miller *et al*. 2010) and the Sperrgebiet (hydrobiids, planorbids and lymnaeids of Bartonian age in chalcedonic limestone at Silica North, Silica South, Chalcedon Tafelberg, Steffenkop and Eisenkieselklippenbake: Pickford *et al*. 2008; Pickford, 2015). These occurrences resemble those found in the Kalahari System, not only by their mode of preservation, but also by the taxa represented, but in addition they are associated with mammalian fossils which provide confident estimates of their geological ages. This means that, on their own, Tertiary freshwater gastropods of Africa do not generally yield accurate biostratigraphic information (in contrast to deep graben lake assemblages such as those from Palaeolake Obweruka, Uganda, which provide important exceptions: Van Damme & Pickford, 1995, 1999, 2003, 2010; Van Damme *et al*. 2010).

From this it is concluded that freshwater snails on their own, do not provide reliable biostratigraphic information for estimating the ages of the strata included in the «Grès Polymorphes».

Palaeoenvironmental indications and silicification environment

The composition of the freshwater gastropod fauna from Simanya indicates that the water bodies in which they lived were fresh and generally well-oxygenated (for *Pila*), and probably shallow and marshy (*Bulinus*, *Ceratophallus*). The cherty fossiliferous blocks often contain well-rounded sand grains and small well-polished quartz pebbles (up to 2-3 mm in diameter) consistent with deposition close to or within a fluvial system. The more chalcedonic facies resembles the marls associated with eutric fluvisols which occur today in the floodplain of the Cubango, with the exception that the Simanya samples have been silicified. Combining the faunal evidence with the sedimentary facies suggests that the fossiliferous deposits accumulated in a floodplain close to the Palaeo-Cubango, probably as short-lived, shallow, somewhat swampy depressions. They were subsequently buried by further fluvial deposition, followed by accumulation of the Kalahari Red Sands (largely aeolian sands), and were then silicified close to the ancient land surface. Mouta & Dartevelle (1952) were of much the same opinion about the depositional environment of the chalcedonic rocks of the Grès Polymorphes.

There has been little detailed discussion concerning the mode of silicification, or the processes that led to near-surface silicification of the chalcedonic rocks of the Kalahari System. Mouta & Dartevelle (1952) thought that it occurred under desert conditions, but the distribution of the siliceous deposits in the region is closely associated with Miombo Woodland (savannah) (Fig. 9) in contrast to desert such as in Kaokoland in which near-surface induration has produced immense quantities of « calcrete » and no silicified deposits.

The Simanya occurrence indicates that silicification occurred near the land surface (1-2 metres beneath the surface) comprised of red unconsolidated sands, and that silicification affected not only deposits of fine sand, but also marls related to eutric fluvisols. Similar near-surface masses of silicified rocks occur widely in DR Congo, Angola, Botswana, Namibia and parts of South Africa (Mouta, 1954, personal observations MP) almost invariably associated with a sand cover and Miombo Woodland vegetation (or near equivalents often referred to as savannah). These silicified rock layers are seldom more than 2-3 metres thick, and are usually underlain by bedrock or by less consolidated fluvio-paludal and terrestrial deposits (the case at Simanya).

In stark contrast, near-surface induration of rocks in Mopane Woodland and related vegetation types, which grow in more arid areas than Miombo categories, such as for example, in Kaokoland, Namibia, almost invariably comprises calcification to produce « calcrete » of various sorts (calcisols and derivatives, Jones *et al.* 2013), but likewise seldom more that 2-3 metres thick, overlying bedrock or poorly indurated sediments. There can be little doubt that climatic conditions largely determined not only the processes of silicification and calcification but also the type of vegetation that grew in the regions.

The silica in the chert and chalcedony at Simanya could have been derived from opal phytoliths (Miombo Woodland is rich in grass cover) or it could have been derived from the dissolution of silica from the superficial sands which blanket the country throughout the region.

There is a possibility that subterranean fungus plays an important role in silica diagenesis in Miombo Woodland settings. Fungus communities are diverse and well-developed in such sub-humid conditions, and often concentrate sugars in their hyphae, producing an alkaline chemical environment in which silica is more prone to dissolve than in acid environments. Reduction of alkalinity by whatever means results in silica precipitation. Because fungal hyphae are concentrated in the superficial layers of the soils, then this is where silicification will preferentially occur.

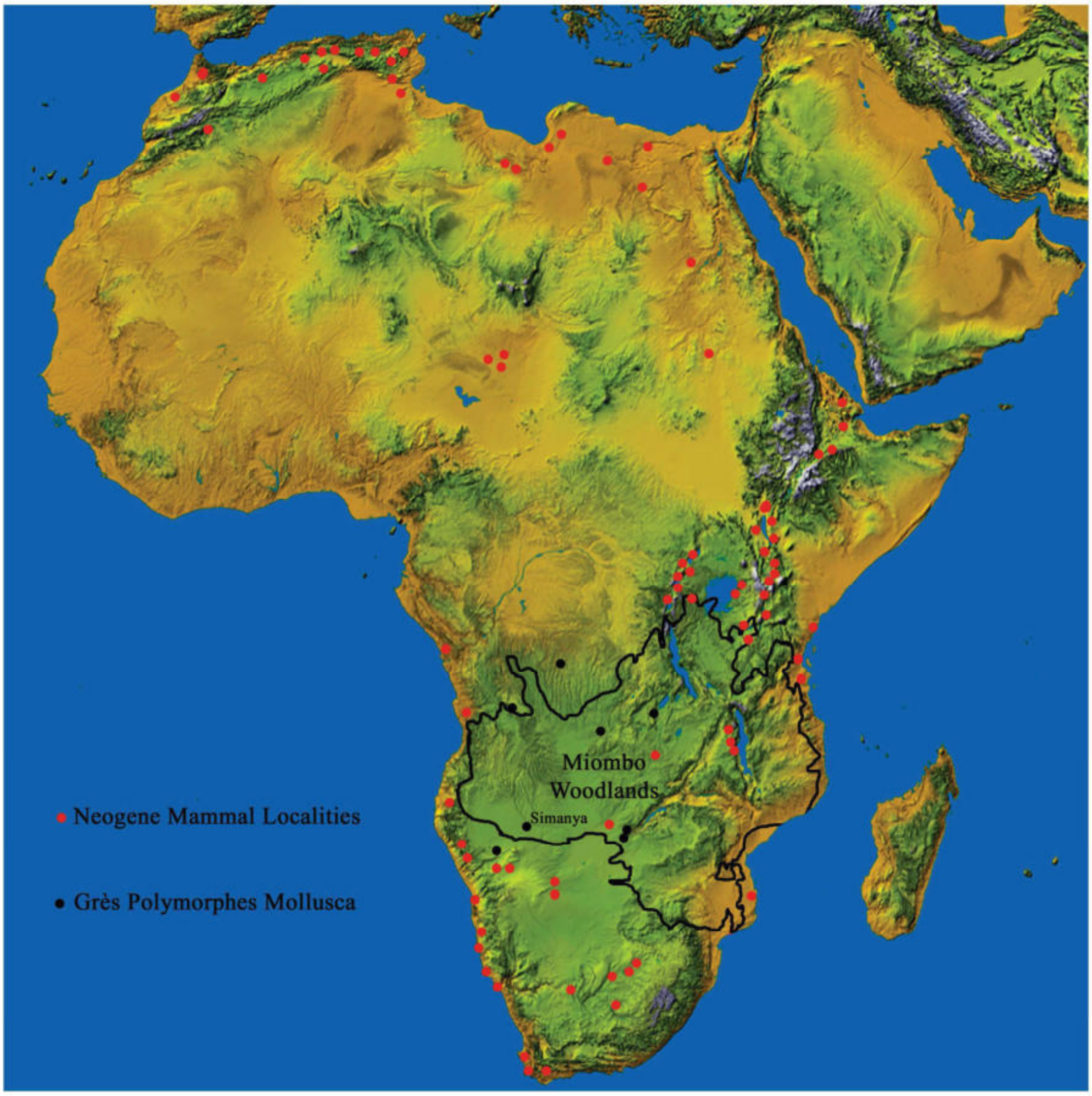

Figure 9. Location of Simanya (Northern Namibia) and other localities which have yielded silicified fossiliferous freshwater deposits attributed to the so-called Grès Polymorphes of Central and Southern Africa (The extent of Miombo Woodland and closely related vegetation types is based on the map of White, 1983).

Comparison of the Simanya molluscan fauna with the extant fauna of the Cubango River

Extant molluscs collected in the Cubango River comprise the gastropod *Bellamya unicolor* and the bivalve *Coelatura* sp. Neither of these molluscs was found in the Simanya chalcedony and chert, but both of them occur in the Pliocene silicified sandstone at Ekuma in Etosha National, Park (Pickford *et al.* 2014). The difference in these faunas is probably related to a differences in habitat – flowing, well-oxygenated water in the Cubango, and probably swampy, somewhat stagnant water for the Simanya fossil fauna.

Simanya Chert as raw material for manufacturing stone tools

An abundance of lithic instruments and flakes is scattered over the flanks of the valley near the Simanya River Lodge. In places it is possible to observe concentrations of flakes suggesting that stone tools were made on site, close to the outcrops of chert. Various completed tools were collected, including discoids worked bifacially all around the circumference (Fig. 10), flakes which show signs of secondary retouch, and « pebble tools » with one end flaked bifacially, the other end left in a natural condition. The raw material for most of the stone tools appears to have been mined from outcrop, or obtained as loose blocks dug up from the soil profile near the oucrops, but a few implements comprise water-worn pebbles probably retrieved from the Cubango River bed or river bank, where blocks of water-polished chert occur.

The bulk of stone tools observed comprise what could loosely be called the Middle Stone Age complex, but some of the « pebble tools » resemble specimens of the more ancient Oldowan culture.

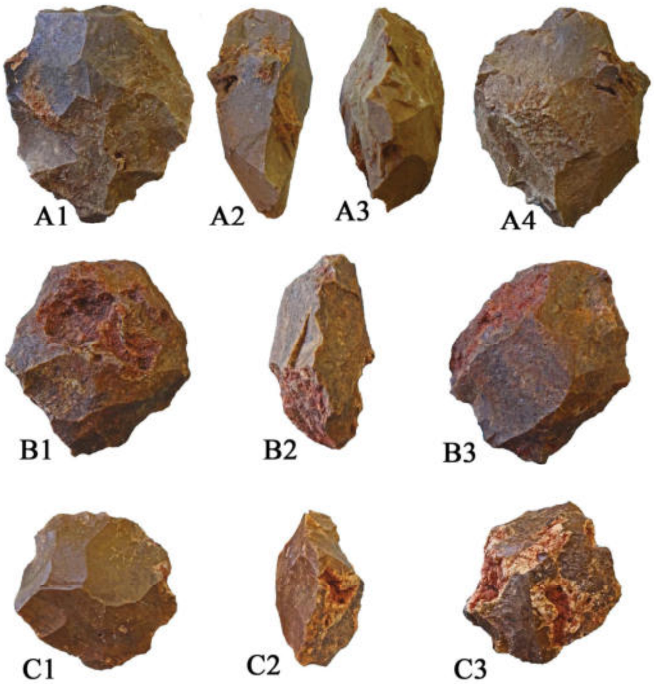

Figure 10. Discoidal, bifacial stone tools from Simanya, Northern Namibia, fabricated from fossiliferous chert-like rock. Specimens are about 5 cm in diameter.

Conclusions

Silicified sands and marls at Simanya, Northern Namibia, contain abundant fossil gastropods, ostracods and a few indeterminate plant remains. Among the gastropods there are several examples of the large ampullariid *Pila* cf *wernei*, and there is an abundance of sinistral snails (three species of *Bulinus*), planorbids (*Ceratophallus*) and small dextral snails (*Tomichia* and an unidentified taxon).

The silicified horizon occurs *in situ* near the top of the southwestern bank of the Cubango River, and is underlain by weakly consolidated fluviatile sands and marls (poorly exposed down to river level). It is overlain by unconsolidated red sand which is widespread in the Kalahari region. In the floor of the Cubango Valley, there is a series of fossiliferous floodplain deposits of Recent age, comprising marls and eutric fluvisols, which provide a depositional analogy for the origin of the silicified deposits prior to their silicification.

Silicification of the Simanya sands and marls appears to have occurred at shallow depths in a savannah environment (notably Miombo Woodland). The stratigraphic and geomorphological position of the Simanya silicified deposits suggest that they are likely to be of Plio-Pleistocene age. They are older than the Middle Stone age on the grounds that the chert has been extensively exploited to manufacture of stone tools.

Acknowledgements

We thank the Simanya River Lodge (Mr Hendrick Kruger and Mrs Francesca Kruger) for alerting us to the existence of fossil molluscs on their property. Support for the palaeontological surveys of the site were provided by the Geological Survey of Namibia (Ministry of Mines and Energy), the French Ministry of Foreign Affairs and Sorbonne Universités (CR2P, UMR 7207 du CNRS, Département Histoire de la Terre, Muséum National d'Histoire Naturelle et Université Pierre et Marie Curie).

References

Anonymous, 1947. Compte-rendu de la Réunion des Géologues du Congo occidental, Lépoldville, 1945. *Bulletin du Service géologique du Congo Belge et de Ruanda-Urundi*, **1**.

Brien, V. 1921. Fossils from the ancient river or lake alluviums which cover the surface of the high plateau of Kundelungu. *Annales de la Société géologique Belge*, **44**, 90-91.

Brown, D.S. 1980. *Freshwater Snails of Africa and their Medical Importance*. London, Taylor and Francis, 487 pp.

Brown, D.S. & Mandahl-Barth, G. 1973. Two new genera of Planorbidae from Africa and Madagascar. *Proceedings of the Malacological Society of London*, **40** (4), 287-301.

Cahen, L. & Lepersonne, J. 1952. Equivalence entre le Système du Kalahari du Congo Belge et les Kalahari Beds d'Afrique australe. *Mémoire de la Société Belge de Géologie, Série* 8 **4**, 1-64.

Connolly, M. 1939. A monographic survey of South African non-marine Mollusca. *Annals of the South African Museum*, **33,** 1-660.

Frankel, J.J. 1964. Terrestrial gastropods in Foraminifera-bearing sediments from the Burman Bush area, Durban. *South African Journal of Science*, **60**, 363-365.

Jones, A. Breuning-Madsen, H. Brossard, M. Dampha, A. Dekers, J. Dewitte, O. Gallali, T. Hallett, S. Jones, R. Kilasara, M. Le Roux, P. Micheli, E. Montanarella, L. Spaargaren, O. Thiombiano, L. Van Ranst, E. Yemefack, M. Zougmoré, R. (Eds) 2013. *Soil Atlas of Africa*. European Commission, Publications Office of the European Union, Luxemburg, 176 pp.

King, L. 1949. On the Ages of the African Land Surfaces. *Quarterly Journal of the Geological Society of London*, **104** (4), 439-459.

King, L. 1951. *South African Scenery. A Text-book of Geomorphology*. 2nd Edition, London, 379 pp. 1 map.

Lepersonne, J. 1945. La stratigraphie du Système du Kalahari et du Système du Karroo au Congo occidental. *Bulletin du Service géologique de Congo Belge et Ruanda-Urundi,* **1**, 27-50.

Leriche, M. 1925. Sur l'âge du calcaire lacustre observé récemment sur le Plateau du Kundelungu (Katanga). *Annales de la Société géologique Belge*, **48**, 128-129.

Leriche, M. 1928. Les fossiles des "Grès Polymorphes" (Couches du Lubilash) aux confins du Congo et de l'Angola. *Annales de la Société géologique de Belgique*, *Publication Relative au Congo Belge, 1927-1928,* **50**, 44-51.

Leriche, M. 1932. A propos des couches du Mont

Bunza. *Association française des Sciences, Compte-rendu de la 56ème session* (Bruxelles, 1932), 229-230.
Leriche, M. 1933. Les fossiles du calcaire lacustre observé récemment sur le Plateau du Kundelungu. *Revue Zoologique Africaine*, **13**, 153-155.
Leriche, M. 1938. Sur les fossiles recueillis dans les Kaiso Beds (Pléistocène inférieur) de la partie congolaise de la Plaine de la Semliki. *Annales de la Société géologique Belge*, **62**, 118-130.
Maufe, H.B. 1929a. Observations sur les calcaires silicifiés du Mont Bunza (Kasaï) et sur la calcédoine du Kalahari de la Rhodésie du Sud. *Annales de la Société géologique Belge, Publication Relative au Congo Belge*, *1928-1929*, **52**, 115-119.
Maufe, H.B. 1929b. The Geology of the Victoria Falls. *Guide Book XV Session International Geologial Congress, South Africa, 1929, Excursion C 20*.
Miller, R. McG. Pickford, M. & Senut, B. 2010. The geology, palaeontology and evolution of the Etosha Pan, Namibia: implications for terminal Kalahari deposition. *South African Journal of Geology*, **113**, 307-334.
Mouta, F. 1954. *Noticia Explicativa do Esboço Geologico de Angola (1: 2,000,000)*. Junta da Investigaçoes do Ultramar, Ministerio do Ultramar, Lisboa, 148 pp, 13 plates.
Mouta, F. & Dartevelle, E. 1952. Sur les «Grès Polymorphes» fossilifères de la Plaine de Cassanje (Malange, Angola) et leur âge. *Comptes Rendus de la 19ème Session du Congrès International (Algérie) Association des Services Géologiques d'Afrique,* **20** (2), 11-24.
Mouta, F. & O'Donnell, H. 1937. Carte géologique de l'Angola au 1: 2,000,000, Notice explicative. *Republica Portuguesa*, *Ministério das Colonias, Lisbon*, 87 pp. 12 pl. 1 map.
Newton, R.B. 1920. On some freshwater fossils from central South Africa. *Annals and Magazine of Natural History,* Series 9, **5**, 241-249.
Pickford, M. 2015. Cenozoic Geology of the Northern Sperrgebiet, Namibia, accenting the Palaeogene. *Communications of the Geological Survey of Namibia*, **16**, 10-104.
Pickford, M. Mocke, H. Ségalen, L. & Senut, B. 2016. Update of the Pliocene fauna of the Ekuma Valley, Etosha, Namibia. *Communications of the Geological Survey of Namibia*, **17**, 115-144.
Pickford, M. Senut, B. Hipondoka, M. Person, A. Ségalen, L. Plet, C. Jousse, H. Mein, P. Guerin, C. Morales, J. & Mourer-Chauviré, C. 2014. Mio-Plio-Pleistocene geology and palaeobiology of Etosha Pan, Namibia. *Communications of the Geological Survey of Namibia*, **15**, 16-68.
Pickford, M. Senut, B. Morales, J. & Sanchez, I. 2008. Fossiliferous Cainozoic Carbonates of the Northern Sperrgebiet. *Memoir of the Geological Survey of Namibia*, **20**, 25-42.
Polinard, E. 1932. La calcédoine à fossiles d'eau douce du Katanga méridional. *Association Française pour l'Avancement des Sciences, Bruxelles, 1932*.
Polinard, E. 1933a. Les formations post-rhétiens du versant méridional du bassin congolais; leurs rapports avec le système du Kalahari. *Annales de la Société géologique Belge*, *Publication Spécial Relative au Congo Belge,* **54**, 1-18.
Polinard, E. 1933b. Découverte de gisements fossilifères d'eau douce sur les versants de la Lubudi, au Katanga méridional. *Annales de la Société géologique Belge*, *Publication Spécial Relative au Congo Belge, 1931-1932*, **55**, 63-82.
Polinard, E. 1933c. Grès polymorphes et calcaires silicifiés. Compte Rendu de la Réunion des Géologues du Bas Congo (April 22, 1933). *Les Chroniques des Mines Coloniales*, (June **1933**) pp. 306-307.
Shaw, P.A. 1985. Late Quaternary landforms and environmental change in northwestern Botswana: the evidence of Lake Ngami and the Mababe Depression. *Transactions of the Institute of British Geographers,* NS **10**, 333-346.
Shaw, P.A. & Thomas, D. 1988. Lake Caprivi: a late Quaternary link between the Zambezi and middle Kalahari drainage systems. *Zeitschriften für Geomorphologie*, **32**, 329-337.
Thomas, D. & Shaw, P. 1991. *The Kalahari Environment*. Cambridge University Press.
Van Damme, D. & Pickford, M. 1995. The late Cenozoic Ampullariidae (Mollusca, Gastropoda) of the Albertine Rift Valley (Uganda-Zaire). *Hydrobiologia*, **316**, 1-32.
Van Damme, D. & Pickford, M. 1999. The Late Cenozoic Viviparidae (Mollusca, Gastropoda) of the Albertine Rift Valley (Uganda-Zaire). *Hydrobiologia*, **390**, 169-215.
Van Damme, D. & Pickford, M. 2003. The late Cenozoic Thiaridae (Mollusca, Gastropoda) of

the Albertine Rift Valley (Uganda-Congo) and their bearing on the origin and evolution of the Tanganyikan thalassoid malacofauna. *Hydrobiologia*, **4**, 1-83.

Van Damme, D. & Pickford, M. 2010. The Late Cenozoic Bivalves of the Albertine Basin (Uganda-Congo). *Geo-Pal Uganda*, **2**, 1-121.

Van Damme, D. Pickford, M. & Musiime, E. 2010. Brief report on Late Miocene molluscs from West Nile, Uganda. *Geo-Pal Uganda*, **2**, 122-128.

Veatch, A.C. 1935. Evolution of the Congo Basin. *Memoir of the Geological Society of America*, **3**, 1-183.

West, K. Michel, E. Todd, J. Brown, D. & Clabaugh, J. 2003. *The Gastropods of Lake Tanganyika. Diagnostic Keys, Classification, and Notes on the Fauna*. Dorchester, Henry Ling, 130 pp.

White, F. 1983. *Vegetation of Africa – A Descriptive Memoir to Accompany the UNESCO / AETFAT / UNSO Vegetation Map of Africa*, Natural Resources Research Report XX, U.N. Educational, Scientific and Cultural Organisation, Paris, 356 pp.