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GEOLOGY AND PALAEOBIOLOGY OF THE NORTHERN SPERRGEBIET, NAMIBIA

by

Dr Martin Pickford[1,2] and Dr Brigitte Senut[2]

[1]Collège de France, and [2]Département Histoire de la Terre, UMR 5143 du CNRS,
Case postale 38, 57, rue Cuvier, 75005, Paris

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Fossiliferous Cainozoic Carbonates of the Northern Sperrgebiet

Martin Pickford[1,2], Brigitte Senut[2], Jorge Morales[3] and Israel M. Sanchez[3]

[1]*Collège de France,*

[2]*UMR 5143 du CNRS, Case postale 38, 8, rue Buffon, 75005, Paris*

[3]*Paleobiologia, Museo Nacional de Ciencias Naturales, CSIC, José Gutierrez Abascal 2, 28006, Madrid*

e-mail : 1) pickford@mnhn.fr, 2) bsenut@mnhn.fr, 3) mcnm166@mncn.csic.es, 4) ims32@cam.ac.uk

During the 2008 field survey of the Namibia Palaeontology Expedition (NPE) attention was focussed on the post-Cretaceous carbonate rocks of the Sperrgebiet in order to determine their ages more precisely. Four new fossil localities were discovered, three of which yielded vertebrates including mammals, as well as plants and abundant freshwater molluscs and land snails. These discoveries are of fundamental importance for improving our understanding of the timing of geological events in the Sperrgebiet. Preliminary identification of the mammal fossils indicates a Middle Eocene (Middle Lutetian) age for the Black Crow Carbonate. The Silica North and Silica South deposits are likely to be slightly older (Early Lutetian) than the Black Crow Carbonate.

Introduction

Cainozoic carbonate rocks are widespread in the Sperrgebiet, but, apart from chalcedonic limestone at Chalcedon Tafelberg and two or three localities in the Namib Calc-crust, have previously yielded few fossils. In 2008, attention was focussed on these rocks to determine whether they contained palaeontological remains. Abundant fossils were found, including plants, molluscs and vertebrates. The mammals in particular will throw a great deal of light on the ages of these deposits which have hitherto been the subject of varying opinions based on clast assemblages, geomorphology and diagenetic features.

It is clear from field relationships that there are diverse bodies of carbonate rock in the Sperrgebiet succession deposited in different geomorphological settings, by a variety of geological processes and suffering divergent diagenetic histories. In order to determine the relative positions of the various carbonate units to each other it is necessary to examine the detailed Cainozoic geological history of the region, which is characterisd by a complex interplay of erosion and deposition in a region that was semi-arid to hyper-arid for much of the time and was exposed to a wide variety of geological processes including pedogenesis, erosion, karstification, fluvio-paludal, littoral marine and aeolian deposition, hydrothermal activity, volcanic action and sinter formation.

All this erosional and depositional activity was played out in a changing palaeoclimate which, after a long period of summer rainfall conditions, came to be dominated by a winter rainfall regime in the Late Miocene, a change that was accompanied by the occurrence of frequent fogs which played a preponderant role in the formation of the Namib duricrust and coastal gypcretes. The former is a regionally widespread crust that formed on virtually all rock types and in many geomorphological settings; including sloping ground. It was called the Namib Calcrete by Van Greunen (undated) but it is not a calcrete but a surface limestone (Kaiser, 1926). We refer to it as the Namib Calc-crust or duricrust. Superficial gypsiferous deposits are generally resticted to a belt close to the present day coast of Namibia.

The only Cainozoic rock units that come close to having a regional presence are widespread but relatively thin boulder conglomerates previously attributed to the Blaubock and Gemsboktal Formations (Stocken, 1978), cemented by Namib Calc-crust. These units overlie a variety of rocks, but were preceded depositionally by variegated marls that accumulated in valleys, dolines and kamenitzas in the region. These conglomerates are thin but exceptionally widespread sheet wash deposits now exposed in many places as classic hamadas (an Arabic word for relatively flat, rock strewn plateaux, often with scarp-like edges). Combined, they provide the only regional key horizons for determining the relative positions of strata with more restricted distribution.

Until 2008, the only vertebrate fossils found in carbonate rocks of the Northern Sperrgebiet were struthious eggshell fragments found in lightly calcified aeolianites at Kalkrücken probably representing *Diamantoris laini*, indicative of a late Miocene age, and in Namib Calc-crust at Elfert's Tafelberg, which yielded eggshells of *Struthio daberasensis*. These regionally widespread purple-brown duricrusts are often rich in shells of the land snail *Trigonephrus*.

Previous work

The published literature on the Cainozoic carbonate rocks of the Northern Sperrgebiet is scant, but unpublished reports by geologists employed by Consolidated Diamond Mines are of interest, even though the interpretations of the rocks are sometimes contentious (Kalbskopf, 1977; Liddle, 1971; Stocken, 1978). In brief, three kinds of post-Mesozoic carbonate deposits have previously been recognised; a) chalcedonic limestone (Beetz, 1926), b) calc sinter (Beetz, 1926), and c) calc-crust (or surface limestone and lime cemented terraces of Kaiser, 1926). Most of these carbonates are dolomitic limestones, parts of which have been silicified, either as plate like masses or as irregularly shaped nodules. Some fossils in the carbonates have also been silicified.

Previous age estimates of these deposits have varied widely, the chalcedonic deposits at Chalcedon Tafelberg originally being reported as a late Cretaceous unit (Beetz, 1926) until an underlying limburgite (or monchiquite) dyke was dated to 15 Ma, after which the deposits were dated to the middle Miocene (Stocken, 1978). Two "calcrete" formations have been recorded (called "Older" and "Younger" calcretes by Van Greunen (undated)) which have been attributed to the Miocene and Pleistocene respectively, but without direct evidence of their ages. Calcsinter deposits are evidently very young, Late Pliocene to Pleistocene, and this is where they have generally been placed by previous researchers (Beetz, 1926; Corbett, 1989; Pickford and Senut, 2000).

Wenz (1926) and Beetz (1926) mentioned the existence of land and freshwater snails in carbonates of the Northern Sperrgebiet, but the detailed stratigraphic contexts of the samples were not sufficiently well recorded for them to be of much stratigraphic or palaeoecological value. No vertebrate fossils have previously been found in the Sperrgebiet carbonates.

Kaiser (1926) and Beetz (1926) erected the basis for the stratigraphy of the post-Gariep deposits of the Sperrgebiet. Right from the start of studies it was recognised that there was a rich variety of Cainozoic deposits in the region, many of which occurred in small patches and which often lacked superpositional relationships with other deposits. By careful mapping and by studying east-west oriented trenches that were spaced 200 metres apart and many km long, Kaiser (1926) and Beetz (1926) managed to infer most of the stratigraphic relationships of the sediments in the region, but they recognised that many questions remained, not least of which concerned the ages of the various mapped units, and in some cases the positions of units relative to each other.

Palaeontology has proved to be crucial to resolving the positions of some of the strata. For example, the maps published by Kaiser (1926) show marls with agates, shark teeth and molluscs northeast of Bogenfels, which were initially thought to be of Miocene age (see legends on the maps). A correction in the monograph indicates that after study of the molluscs from these strata the age of the unit had to be revised to Eocene, but since the maps had already been printed it was too late to change the legends. This unit is now generally known as the Granitberg Beds (Miller, 2008) (or sometimes as the Buntfeldschuh Formation although the latter unit is likely composed of sediments of various ages) (Siesser and Salmon, 1979; Stocken, 1978).

Detailed mapping by CDM geologists (Barbieri, 1968; Greenman, 1966, 1970; Liddle, 1971; Kalbskopf, 1977; Van Greunen (undated)) led to some modifications of the results of Kaiser (1926) mainly by extending the geological mapping eastwards as far as the Klinghardt Mountains, but by and large, these later works, which remain unpublished, tended to support the pioneer results of the German geologists, the changes made being cosmetic rather than fundamental.

In addition, because of questions concerning the origin of the diamond placer deposits of the Sperrgebiet, geologists were interested in re-examining in detail all the results of Kaiser (1926), as well as to carry out mapping and drilling of suspected kimberlitic pipes in the region. Circular carbonate-filled depressions ranging in diameter from a few hundred metres to a few km cropping out to the west of, and close to the Klinghardt Mountains were mapped and drilled, and three structures (Chalcedon Tafelberg, Black Crow, Steffenkop) were examined but not drilled in the Granitberg-Pomona sector west of the Chameis-Rotkop road. The expectation that these circular structures represented volcanic craters became deep-seated in the minds of geologists, as did the tendency to interpret clastic deposits beneath the carbonate caps as pipe infillings of kimberlitic to para-kimberlitic affinities. With the exception of Chalcedon Tafelberg, no fossils were reported from these carbonate deposits or from the underlying softer marly sediments.

The presence of abundant chalcedony and other siliceous clasts in the diamondiferous Eocene and Miocene deposits of the Sperrgebiet focussed attention on the silicified deposits of the region, as they were considered to be the source of some of the indicator clasts in potentially diamondiferous deposits. As a result, the presence of silicified ferruginised bedrock and silcrete capping tafelberge in the region caused much comment (Beetz, 1926; Liddle, 1971; Stocken, 1978), with most authors correlating the silicification to the Late Cretaceous. In the end all siliceous deposits in the Sperrgebiet came to be correlated to the Late Cretaceous, despite the fact that there are various types of silicification affecting a great variety of rocks, including weathered basement (Gariep Dolomites, quartzites, schists and gneisses), presumed Oligocene sediments underlying volcanic rocks at Swartkop, and Cainozoic carbonate bodies at Chalcedon Tafelberg.

The chalcedonic limestones at Chalcedon Tafelberg were removed from the Cretaceous and correlated to the Middle Miocene as a result of radioisotopic dating of the limburgite (or monchiquite) which is beneath the limestone (Stocken, 1978). Ages around 15 Ma were obtained for this volcanic rock, but since it is an intrusive, dyke-like body, it could be younger than the limestones rather than older than them, although Stocken (1978) reported that overlying sediments contained fragments of monchiquite, in which case the sediments would be younger than the dyke rock.

The NPE survey of 2008

The Namibia Palaeontology Expedition located four new fossiliferous outcrops of carbonate rocks in the Sperrgebiet and reinterpreted previously recognised deposits (Fig. 1). The new fossiliferous deposits are at Silica North, Silica South, Black Crow Depression and Steffenkop and all of them appear to infill kamenitzas developed in Gariep Dolomite. Kamenitzas are solution pans, usually circular or oval in plan, with flat bottoms and rounded edges. Dolines in contrast are deeper and often contain sedimentary deposits, resulting from the fact that they represent sink holes.

A small outcrop at Gamachab previously mapped as calc-sinter (Kaiser, 1926; Wenz, 1926) is here identified as chalcedonic limestone. The large outcrop of calc-sinter at Gamachab is indeed a Pleistocene sinter deposit.

The newly discovered fossil-rich carbonate outcrops are small (less than 0.5 km in diameter) yet are extraordinarily rich in fossils, principally freshwater molluscs, but also ostracods, land snails, reptiles and mammals. Because the various occurrences are geographically well separated from each other and the carbonate facies between and within the successions are repetitive, it is not possible to correlate in detail between them, but it is clear that there were at least two separate periods of deposition, and perhaps as many as four, separated by discordances. In general the outcrops are circular to oval in plan, and the strata tend to dip towards the centres of the outcrops, sometimes at high angles (10° or more in some cases) suggesting that the deposits accumulated in small, steep-sided depressions. In all cases the depressions are in Gariep Dolomite, and in one case (Chalcedon Tafelberg) a thickness of more than 30 metres of sandy marl underlies the carbonates. This evidence suggests

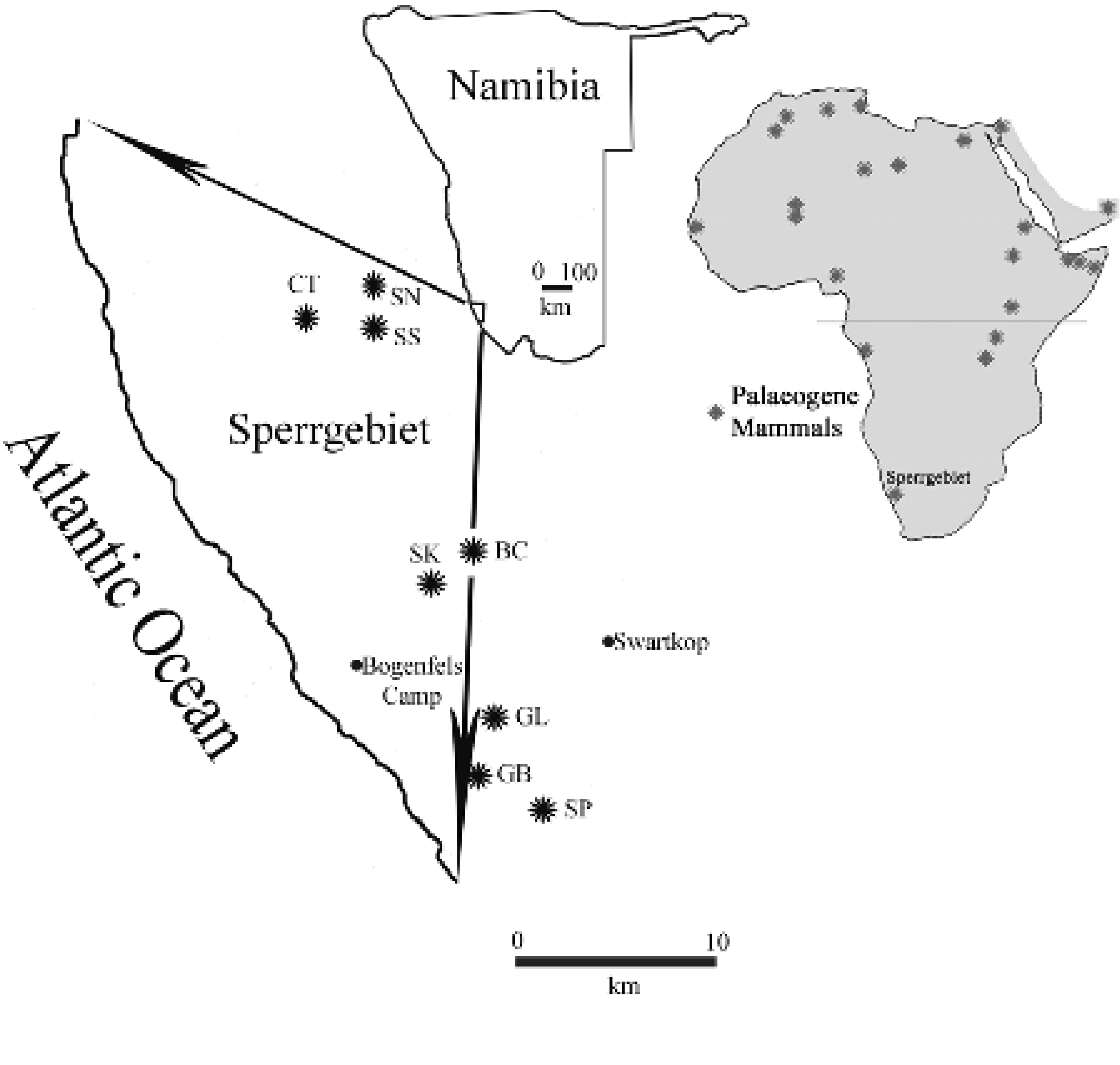

Figure 1. Palaeogene mammal sites in Africa, and distribution of freshwater and pedogenic carbonate deposits in the Northern Sperrgebiet, Namibia. BC – Black Crow, CT – Chalcedon Tafelberg, GB – Gamachab, GL – Glastal, SK – Steffenkop, SN – Silica North, SP – Strauchpfütz, SS – Silica South.

accumulation in kamenitzas and dolines dissolved into dolomitic bedrock, and if so, then the carbonates would be superficial expressions of deposition in epikarstic depressions. Kaiser (1926) already mapped a number of sediment filled doline depressions in the Sperrgebiet, none of which possessed carbonate caps. It would thus appear that in most instances, the "dolines" were dry, but in a few cases became flooded towards the end of their infilling histories, producing small playas or pans which were rapidly colonised by water loving plants (algae, sedges, reeds) freshwater molluscs and vertebrates (crocodiles, fish, birds).

Sedimentation in these kamenitza pans was uniformly fine grained and rich in carbonates, usually dolomitic limestones, but some of them contain pebbles and smaller clasts derived from older rocks exposed in the vicinity. In general, though, these carbonates are extremely pure, the proportion of clastic particles being much less than 0.1%.

An alternative, but less likely scenario is that palaeovalleys draining dolomite country became blocked, thereby forming ephemeral lakes and swamps which filled with carbonates.

Five of the known carbonate deposits suffered partial to complete post-depositional silicification, especially towards the bases of the carbonate bodies, producing important volumes of chalcedony and chalcedonic limestone. The most extensively silicified of these deposits is at Chalcedon Tafelberg, in which the uppermost layers of carbonate were so extensively silicified that there remains very little carbonate. Fossil molluscs and plants in these layers are completely silicified. Lower in the Chalcedon Tafelberg succession there is more carbonate preserved, and some of the chalcedony infills vertical fissures in carbonate and underlying marls, indication that most if not all of the silicification was post-depositional. In some instances, the presence of laterally extensive, well bedded plate-like silicified limestone layers suggest that silicification may have occurred almost syndepositionally with the carbonates. In three of the occurrences, weathered bedrock fringing the carbonate bodies has also been extensively silicified, and in four cases unweathered Gariep Dolomite has been leached and silicified producing a pale silicified carbonate that can be confused with subjacent Cainozoic carbonates. Kaiser (1926) reported the presence of freshwater limestone outcrops at Eisenkieselklippenbake, but the occurrence was erroneously thought to be comprised of leached and silicified Gariep Dolomite, by Liddle (1971). It contains freshwater snails.

Black Crow

The most interesting of the Cainozoic carbonate bodies from the point of view of its geological setting, the completeness of its stratigraphic record, and its palaeontological content, is at Black Crow (Kalbskopf, 1977). This area, which is 9 km north-east of Bogenfels Ghost Town, at an altitude of 190 metres, preserves the most complete stratigraphic section known for the Cainozoic carbonate bodies of the Sperrgebiet (Fig. 2, 3).

The Black Crow deposits lie unconformably on Gariep Dolomites and quartz veins and quartzites. The oldest of the post-Gariep units is represented by well bedded, fine grained quartzites disposed almost horizontally on the dolomite substrate. The quartzites have been deeply eroded and now occur as discontinuous outcrops to the northwest, west, southwest and southeast of Black Crow. These quartzites which are locally 0.5 – 1 metre thick, were correlated to the Pomona sequence by Kaiser (1926) and we see no reason to disagree with this suggestion, even though the Black Crow occurrence is far from the type locality.

In the topographically lowest part of the Black Crow depression there is a conglomerate which contains phonolite cobbles up to 10 cm in diameter. Kalbskopf (1977) reported that these cobbles had been hydrothermally altered, and whilst many of the cobbles in the depression sport a hard outer crust and a softer internal part, it is not clear whether the phenomenon is related to hydrothermal activity or to near surface silicification. Kalbskopf (1977) interpreted the conglomerate as a crater infill, predating carbonate deposition. Elsewhere in the Sperrgebiet, phonolite-bearing conglomerates are attributed to the Gemsboktal Formation (or the so-called younger gravels of Kaiser (1926) and Van Greunen (undated)). Further study is required to determine the age and relative position of this phonolite-bearing conglomerate, which, locally, is confined to the Black Crow Depression and the drainage line immediately south of it (Fig. 2).

Unconformably above the bedded quartzites there is a succession of well-bedded chalcedonised carbonates 3 – 6 metres thick overlying weathered and discoloured dolomite which displays a ferruginised or leached and silicified upper surface. The basal platy silicified carbonate contains plant remains and small gastropods (*Tomichia* sp.).

Unconformably above the chalcedonised carbonates, there is a 3 – 6 metre thickness of fossiliferous dolomitic limestone, often with vertically oriented pedotubules or plant stem moulds which are usually lined with quartz druzes. This carbonate contains a few reworked plates of chalcedonic limestone and bedded quartzite. It yields terrestrial molluscs, crocodiles and mammals. Among the latter are carnivorans, rodents, primates, hyracoids, a possible macroscelidid and an embrithopod.

Lying unconformably on the latter unit, here called the Black Crow Carbonate, there is a thickness of 1 – 2 metres of coarse conglomerate attributed to the Blaubock Formation, as it appears not to contain any phonolite cobbles. This conglomerate is developed regionally, covering tens of square km (Kaiser, 1926; Miller, 2008; Stocken, 1978; Van Geunen

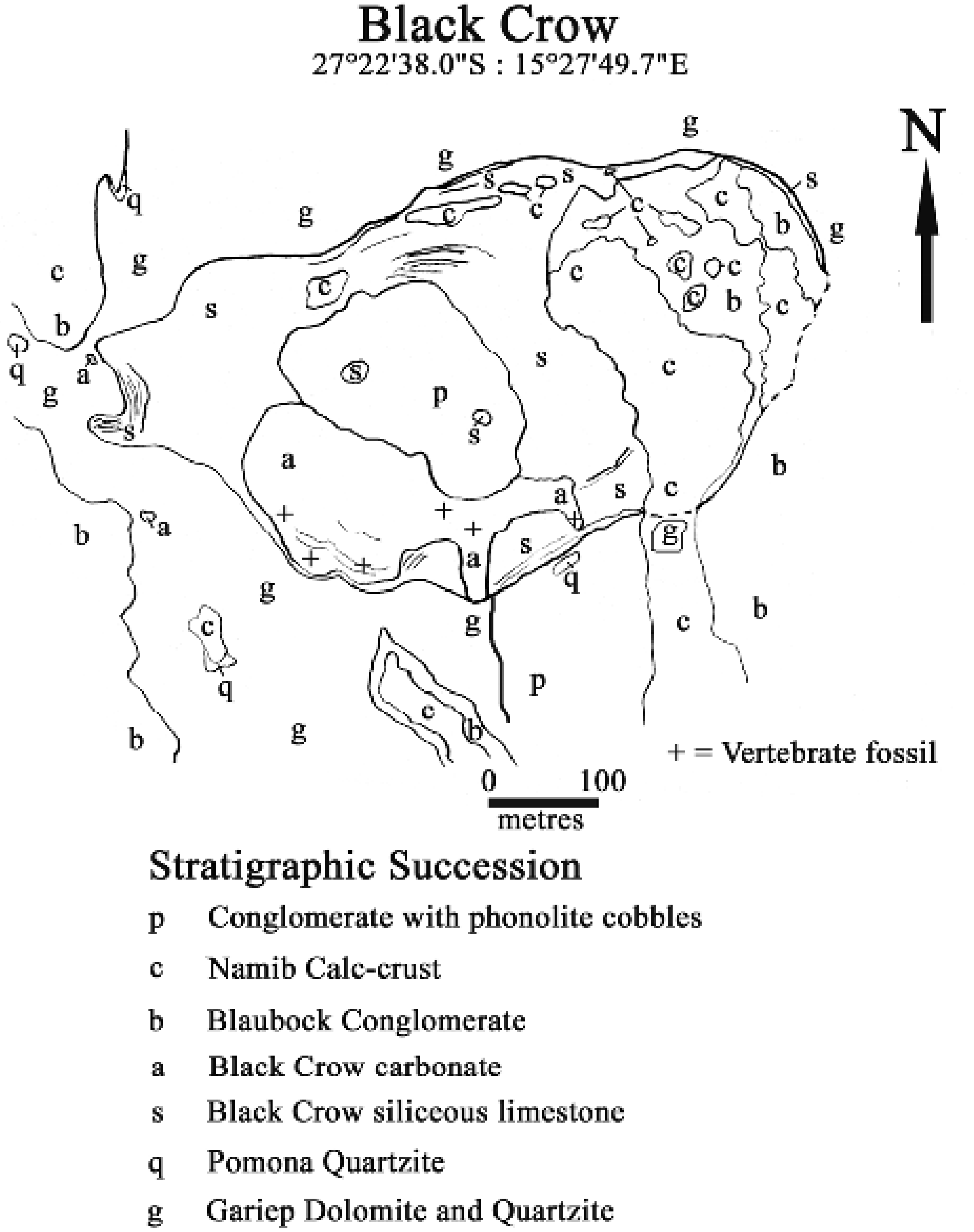

Figure 2. Geological sketch map of the Black Crow Depression, Northern Sperrgebiet, Namibia.

(undated)).

In the Bogenfels Felder 21 area, in which the Black Crow Depression is located, the Blaubock Formation forms a typical hamada topography, with boulder covered, horizontal surfaces bordered by low scarps. This is because the upper parts of the unit have been cemented by the Namib Calc-crust, (the so-called surface limestone and lime cemented terrace of Kaiser, 1926, and the Namib Calcrete of Van Greunen, (undated)) a purple to brown lime-rich duricrust that is extremely widespread in the Sperrgebiet. At Elfert's Tafelberg, this calc-crust has yielded

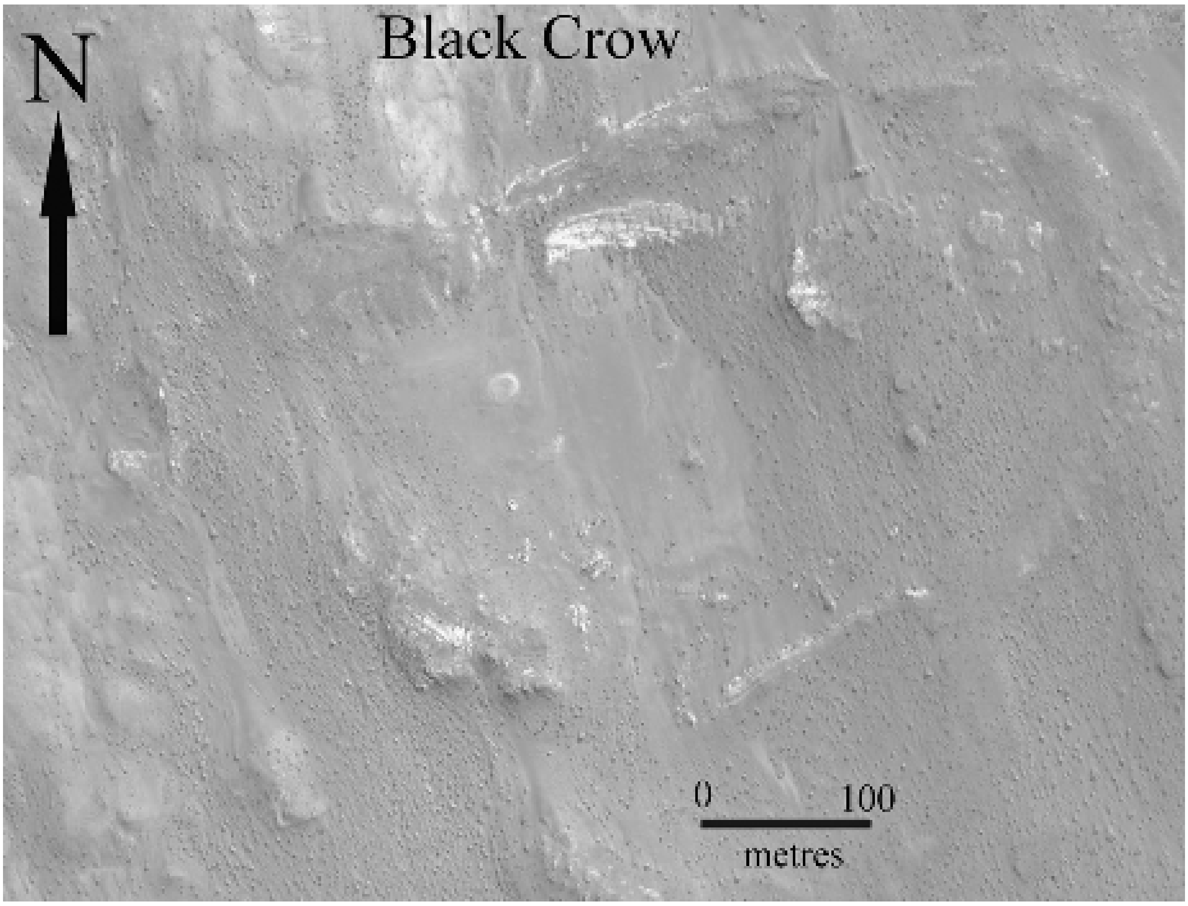

Figure 3. Satellite image of the Black Crow Depression, Northern Sperrgebiet, Namibia, modified from Google Earth.

egg shells of *Struthio daberasensis*, indicating an early Pliocene age for that part of it. The same deposit often contains shells of the land snail *Trigonephrus*.

The most recent rocks in the vicinity of Black Crow are loose aeolian sands and quartz granule lags.

Steffenkop

7 km north-east of Bogenfels Ghost Town, there is an elongated hill capped by dark brown siliceous rocks, surrounded by several small outliers of similar rocks. Initially interpreted by Kalbskopf (1977) as a limestone capping a volcanic crater, the deposit is a deeply silicified ferruginous weathered horizon developed on dolomite. However, the deposit is heterogeneous, and among blocks of silicified weathered dolomite occur silicified carbonates containing abundant small gastropods (probably *Tomichia* sp.) (Fig. 4, 5). Some cobbles of silicified limestone retain fine, wrinkled laminations, suggestive of algal mats. Unconformably overlying the chalcedonic deposits is a gravelly marl and the Blaubock Conglomerate, cemented by Namib Calc-crust. The most recent deposits in the vicinity are gravelly slope wash deposits containing cobbles of all the rock types in the locality, loose aeolian sand and granule lags in valley bottoms.

Silica North

The oval outcrop of carbonate at Silica North is 4 km east of Chalcedon Tafelberg (Fig. 1, 6, 7). Unconformably overlying Gariep Dolomite is a succession of siliceous limestones which contains vast quantities of freshwater gastropods. There are also a few ostracods, terrestrial gastropods, plant remains, and vertebrates, including ranoid and pipid frogs (Rage pers. comm), crocodiles, rodents and hyracoids. These deposits are here called the Silica North Carbonates.

Unconformably overlying the carbonates is a coarse conglomerate attributed to the Blaubock Conglomerate, since it contains no phonolite cobbles. The conglomerate entered the basin from the south (235 m) and exited to the northeast (225 m) (Fig. 6). The upper surface of this conglomerate has been cemented by the Namib Calc-crust. The youngest rocks in the area are loose aeolian sand and granule lags.

Silica South

At Silica South, 4.2 km southeast of Chalcedon

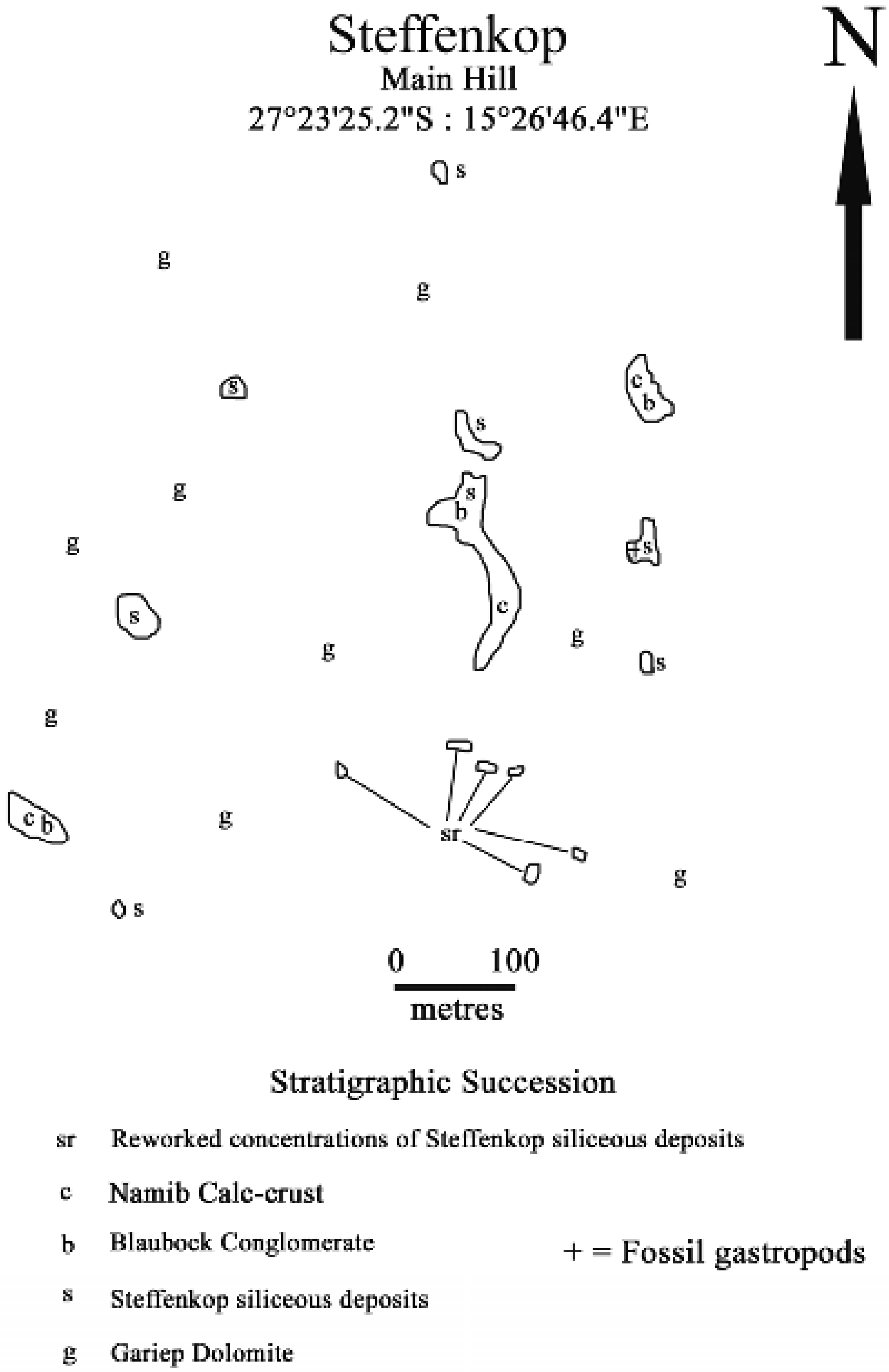

Figure 4. Geological sketch map of Steffenkop, Northern Sperrgebiet, Namibia.

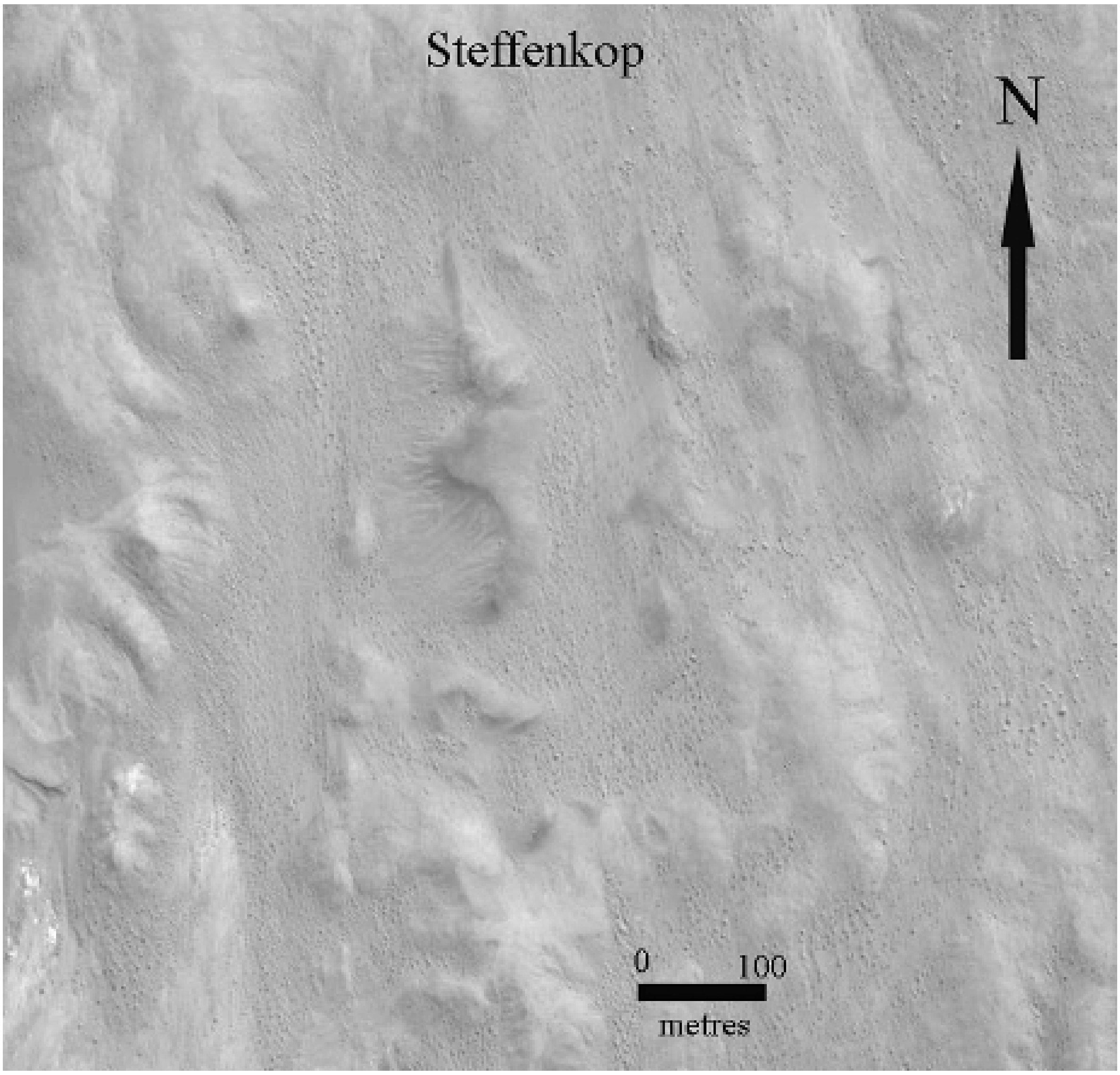

Figure 5. Satellite image of Steffenkop, Northern Sperrgebiet, Namibia, modified from Google Earth.

Tafelberg (Fig. 1), there is an almost circular outcrop of well bedded freshwater limestone which contains abundant freshwater gastropods and plant remains (Fig. 8, 9). The basal layers of carbonate have been silicified, producing plates and nodules of chalcedony floating in carbonate. Many gastropods are silicified and weather out in positive relief. The deposits have yielded hyracoid and rodent teeth as well as fish vertebrae and scales, and ranoid and pipid frog bones (Rage pers. comm.).

Unconformably overlying the carbonates is a coarse conglomerate, the Blaubock Conglomerate, the upper surface of which has been subjected to lime cementing. The conglomerate entered the basin from the southeast (235 m) and existed from it in the northwest (221 m). The youngest rocks in the area are loose sand and granule lags.

Chalcedon Tafelberg

Chalcedon Tafelberg (Fig. 10, 11) has been the subject of comment on several occasions (Kaiser, 1926; Liddle, 1971; Stocken, 1978). It is a doline although Liddle (1971) thought it was a volcanic crater produced by explosive eruptions of tuff. The depression in which the deposits occur was formed in Gariep Dolomite. The lowermost outcrops consist of sandy marls over 30 metres thick (base not exposed). A limburgite (or monchiquite) dyke cuts through these marls and terminates less than a metre beneath the carbonate layers near the top of the hill. There are 4 or more metres of chalcedonic limestone at the top of the hill, the uppermost layers of which are comprised almost completely of chalcedony. On the south and east sides of the hill, there is a 2-3 metre layer of marl between a lower carbonate horizon and the up-

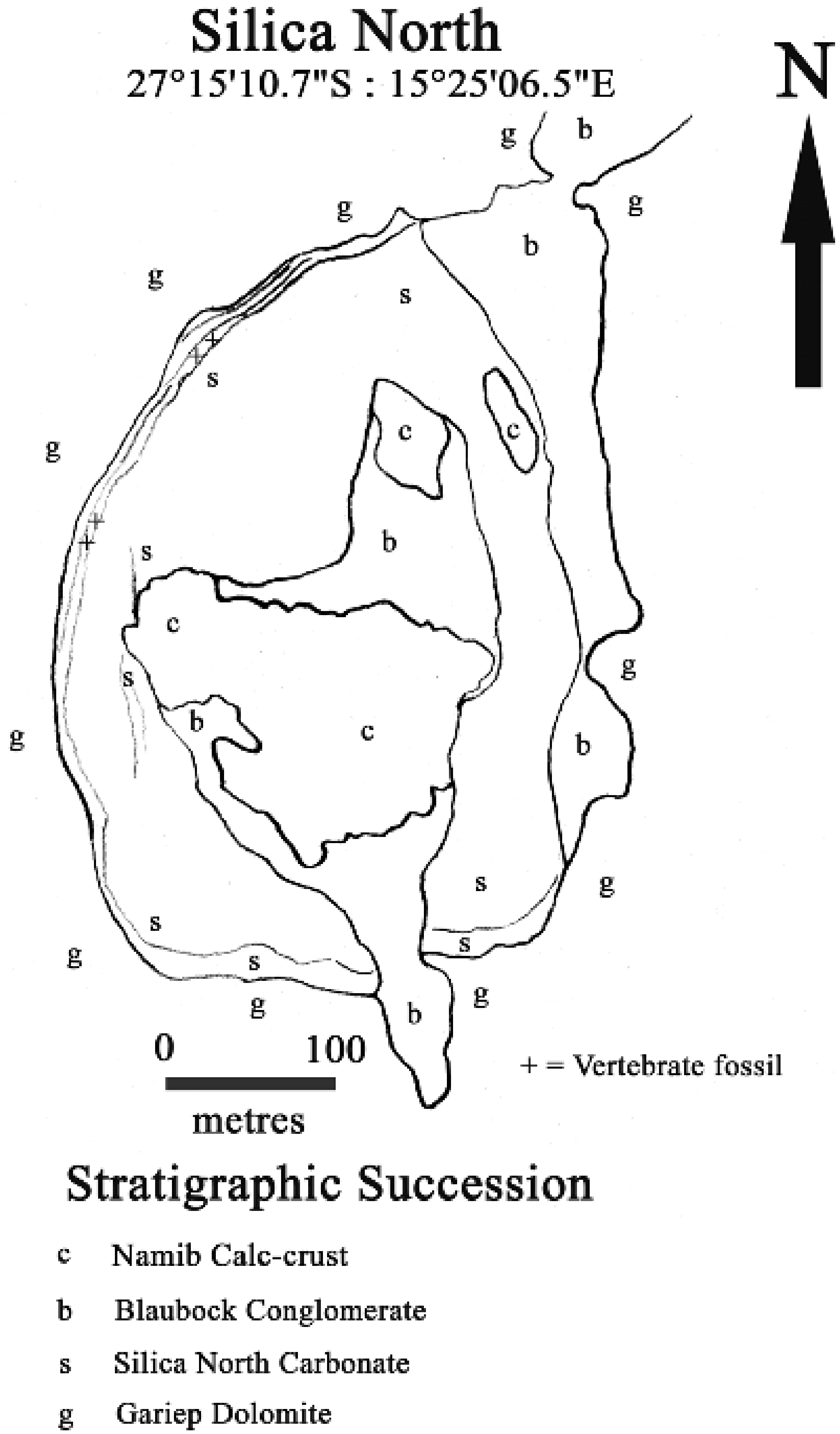

Figure 6. Geological sketch map of Silica North, Northern Sperrgebiet, Namibia.

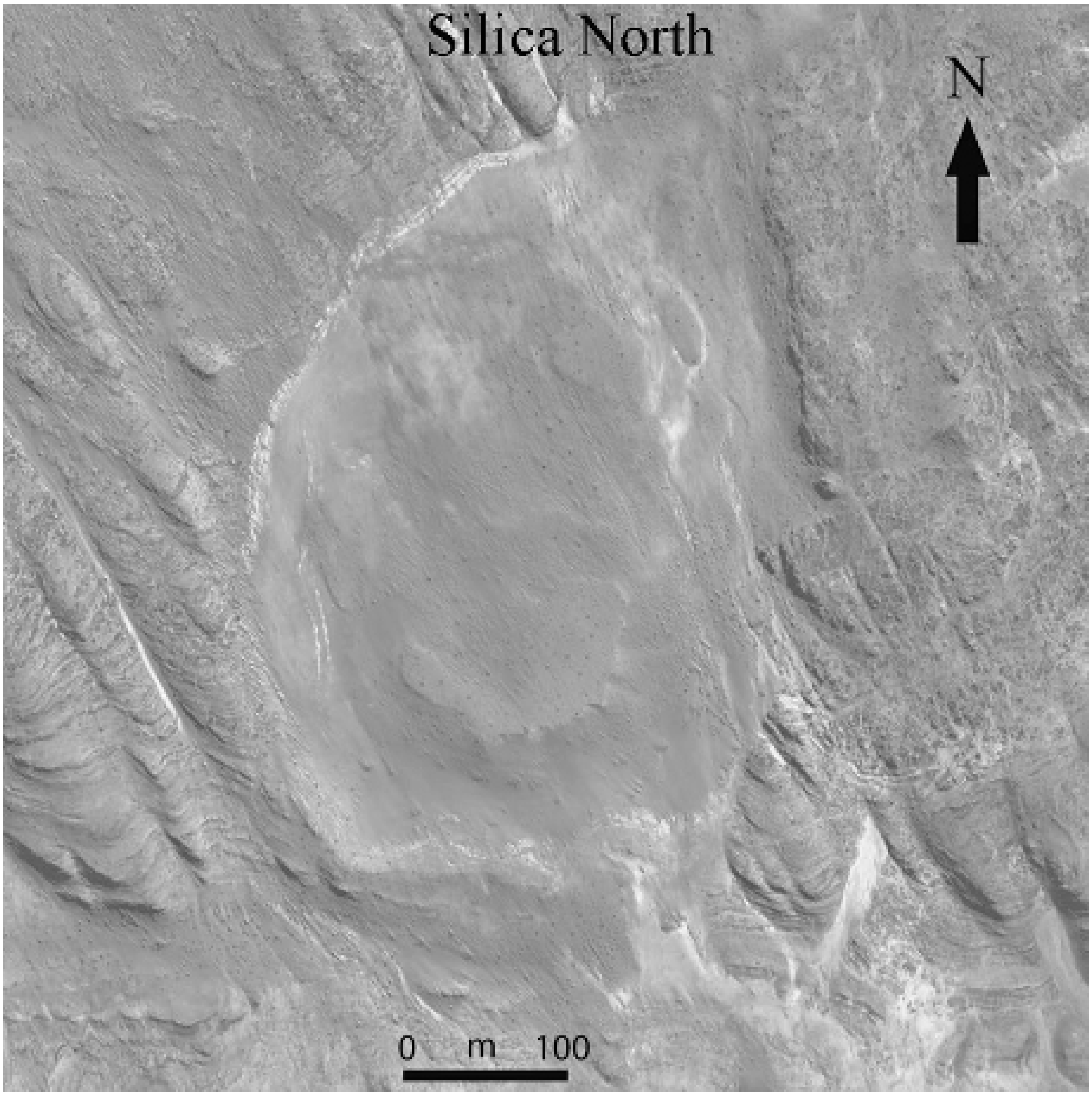

Figure 7. Satellite image of Silica North, Northern Sperrgebiet, Namibia, modified from Google Earth.

per carbonate layers.

Overlying the hill and draping down its northern slopes is a lime-bearing duricrust attributed to the Namib Calc-crust. The youngest rocks in the area are scree fringing the Chalcedon Tafelberg on its northern and southern sides, loose aeolian sand and granule lags.

Eisenkieselklippenbake

The report of freshwater limestone at Eisenkieselklippenbake (Kaiser, 1926) appears to be based on the occurrence of silicified Gariep Dolomite, not unlike outcrops at Black Crow, Silica South and Silica North. Liddle (1971) was the first to reclassify this deposit (but incorrectly so, as it contains freshwater gastropods and plant remains).

Gamachab East

At Gamachab there is an areally extensive calc sinter deposit cementing aeolian sands and draping a ridge of basement rocks (Fig. 12). This sinter is probably Pleistocene.

East of the main mass of calc sinter, however, there is a small area of carbonate rocks included in this category by Kaiser (1926). This deposit yielded a specimen of large *Dorcasia* (Wenz, 1926). Our examination of the occurrence in 2008, revealed that it is not calc sinter, but is silicified freshwater limestone similar to the Black Crow occurrence (Fig. 1), and it is underlain by silicified Gariep Dolomite.

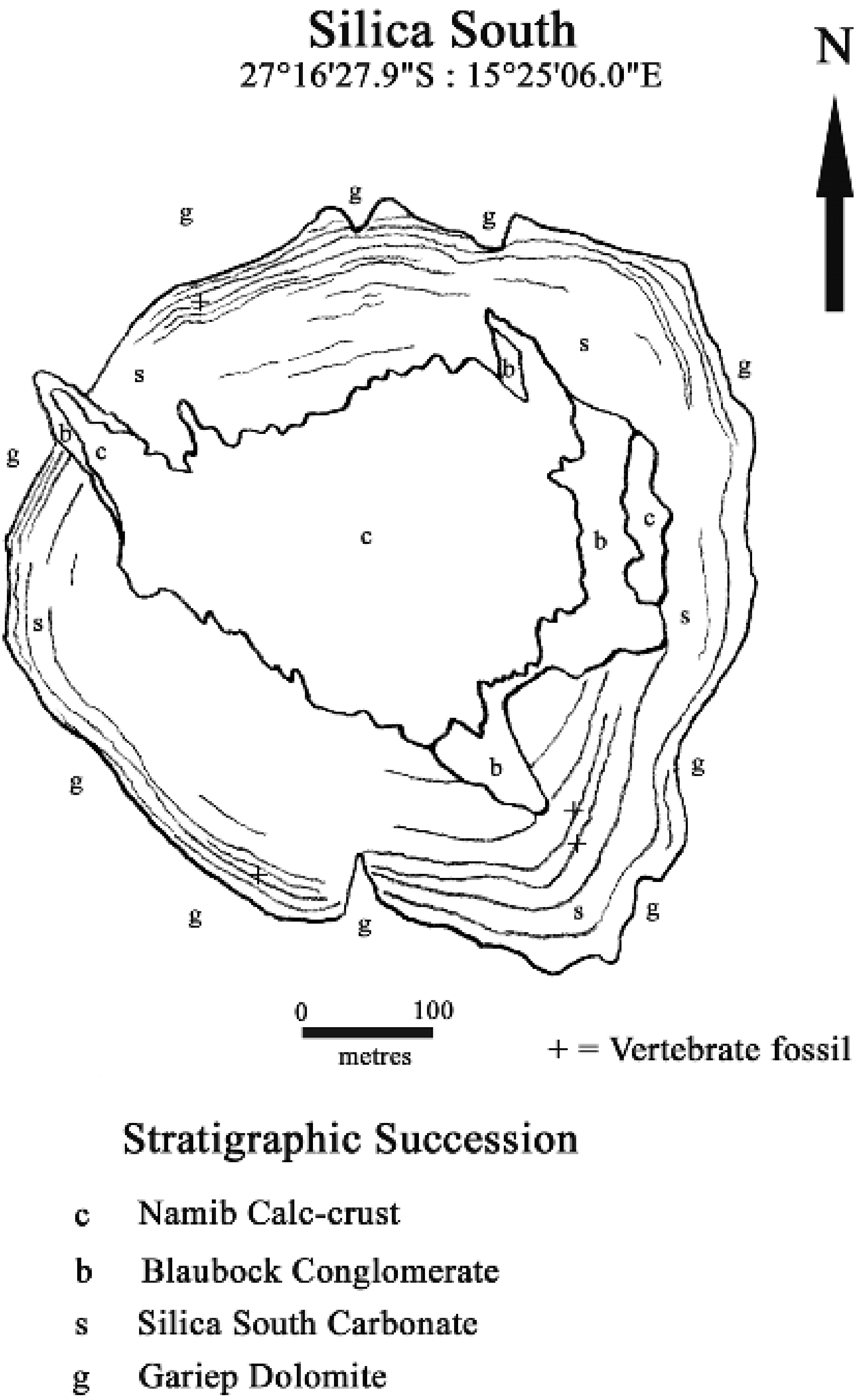

Figure 8. Geological sketch map of Silica South, Northern Sperrgebiet, Namibia.

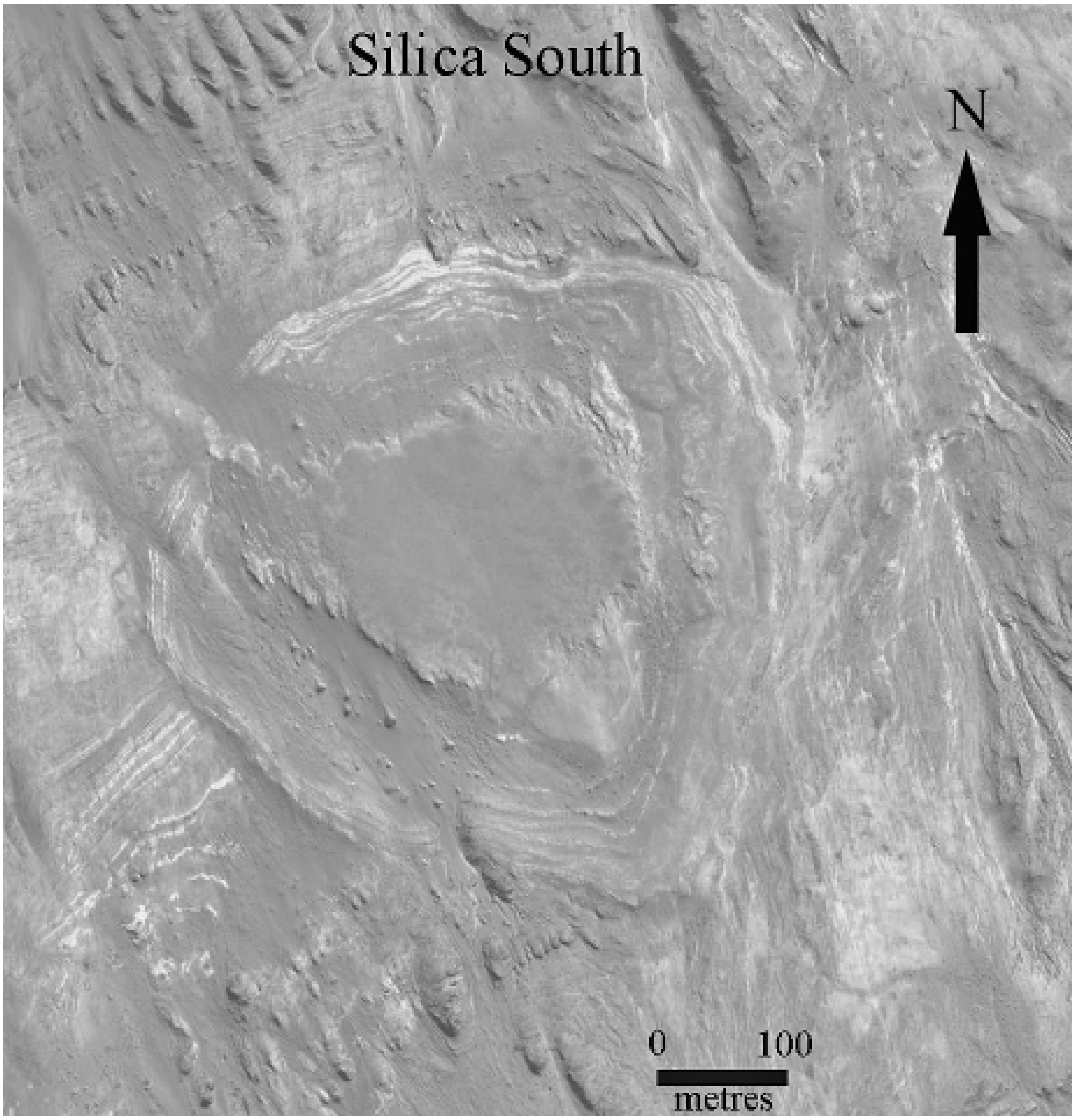

Figure 9. Satellite image of Silica South, Northern Sperrgebiet, Namibia, modified from Google Earth.

Strauchpfütz

The carbonate horizons at Strauchpfütz are pedogenic calcretes, as shown by their nodular bases passing upwards into massive calcrete comprised of conjoined nodules. Between the four main layers of calcrete there are soft marly layers with calcareous nodules, similar to those that occur at the Early Miocene Glastal and Langental mammal localities. At one locale positioned between the third and fourth calcrete layers, there is a small patch of nodular marl rich in the remains of freshwater gastropods (Pickford, this vol.).

These calcretes overlie marls with agates, chalcedony and jasper which are attributed to the Buntfeldschuh Formation, and they lap on to Basement rocks (Fig. 13). Further details about the Strauchpfütz carbonates are given in Pickford (this volume). They are probably of Early Miocene age.

Reuning's Pipe

Blocks of carbonate in the depression known locally as Reuning's Pipe have yielded freshwater gastropods (Pickford, this volume). The fossiliferous carbonate is radically different from the larger outcrops of freshwater limestone that occur extensively in the region, which are generally unfossiliferous or contain only rare plant remains.

The gastropod bearing carbonate at Reuning's is therefore likely to be a younger deposit, possibly of Eocene age. It is overlain by two conglomerates one

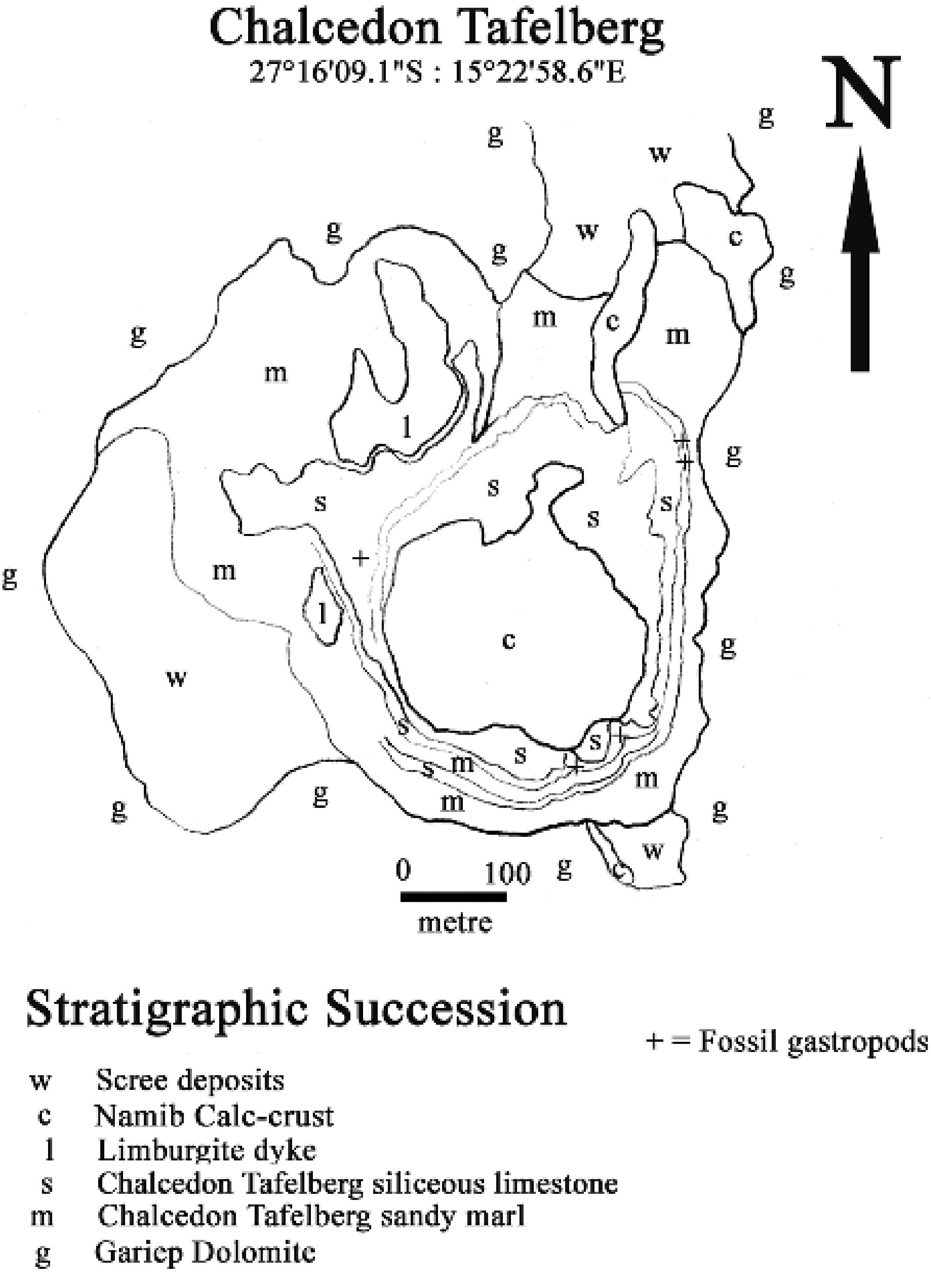

Figure 10. Geological sketch map of Chalcedon Tafelberg, Northern Sperrgebiet, Namibia.

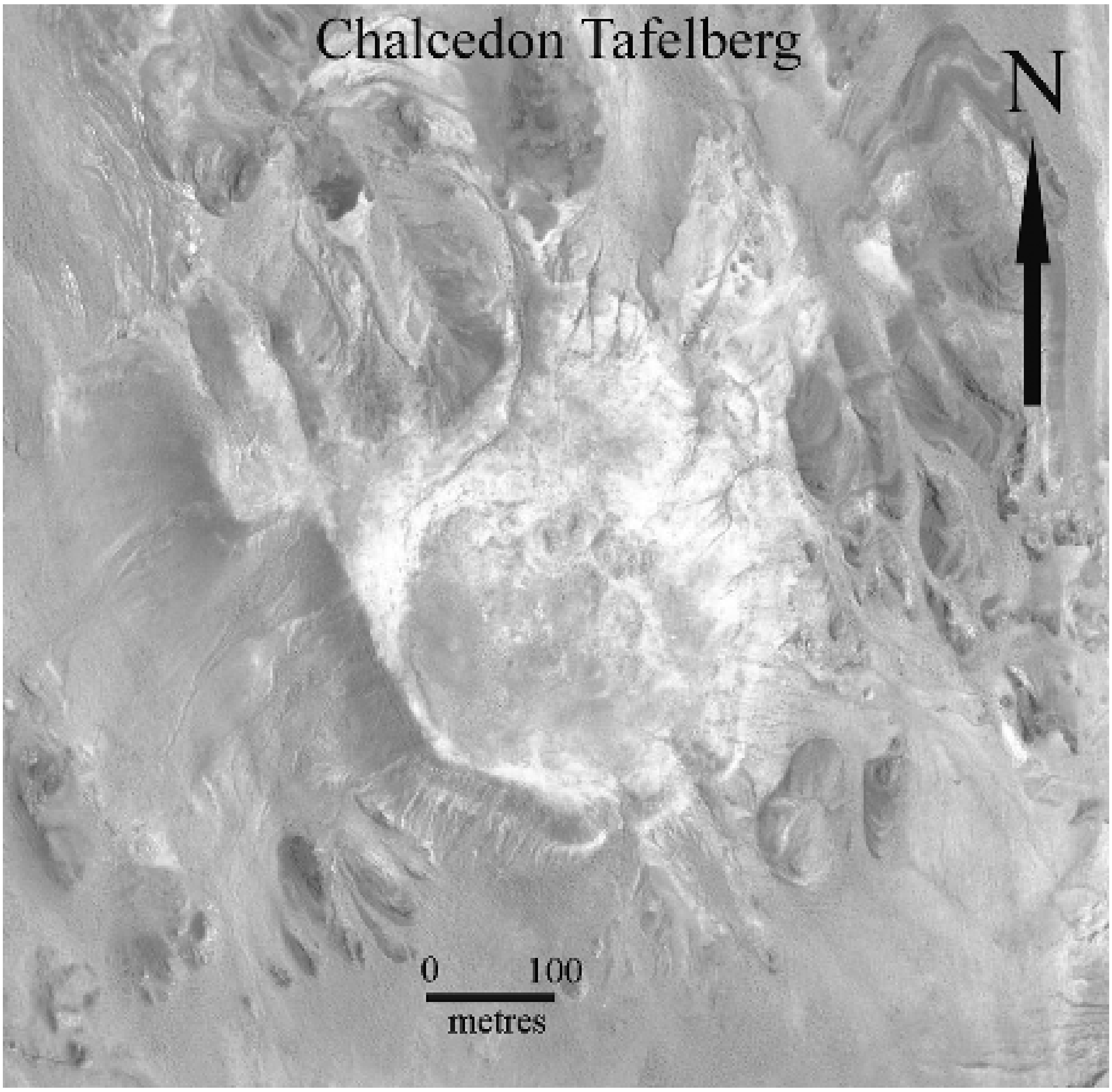

Figure 11. Satellite image of Chalcedon Tafelberg, Northern Sperrgebiet, Namibia, modified from Google Earth.

without phonolite (Blaubode Conglomerate) and another rich in phonolite cobbles (Gemsboktal Conglomerate) and there is abundant calc-crust (Namib Calc-crust) in the vicinity containing shells of *Trigonephrus*.

Vlei 315

Kaiser (1926) recorded the presence of freshwater gastropods at Vlei 315, 2 km south of Loch Kuppe, south of the Klinghardt Mountains. The NPE visited this locality and found it to be pleistocene.

Grillental VI Valley Carbonates

In a valley leading northwards into the Grillental, just south of the rich fossil locality Grillental VI, there are outcrops of calcrete either side of fluvial deposits of Early Miocene age (Fig. 14). These calcretes appear to be valley calcretes formed at the edges of the valley they contain freshwater gastropods.

Discussion

Re-examination of carbonate rocks in the Northern Sperrgebiet reveals that they are generally extremely richly endowed with fossils, principally freshwater gastropods, but also ostracods, land snails and vertebrates. The commonest vertebrates are crocodiles, but there are also fish, frogs, birds and mammals.

Hitherto, the ages of the chalcedonic carbonates in the Sperrgebiet have been estimated to be Middle Eocene or earlier, on the grounds that Eocene marine deposits contain chalcedony thought to have been

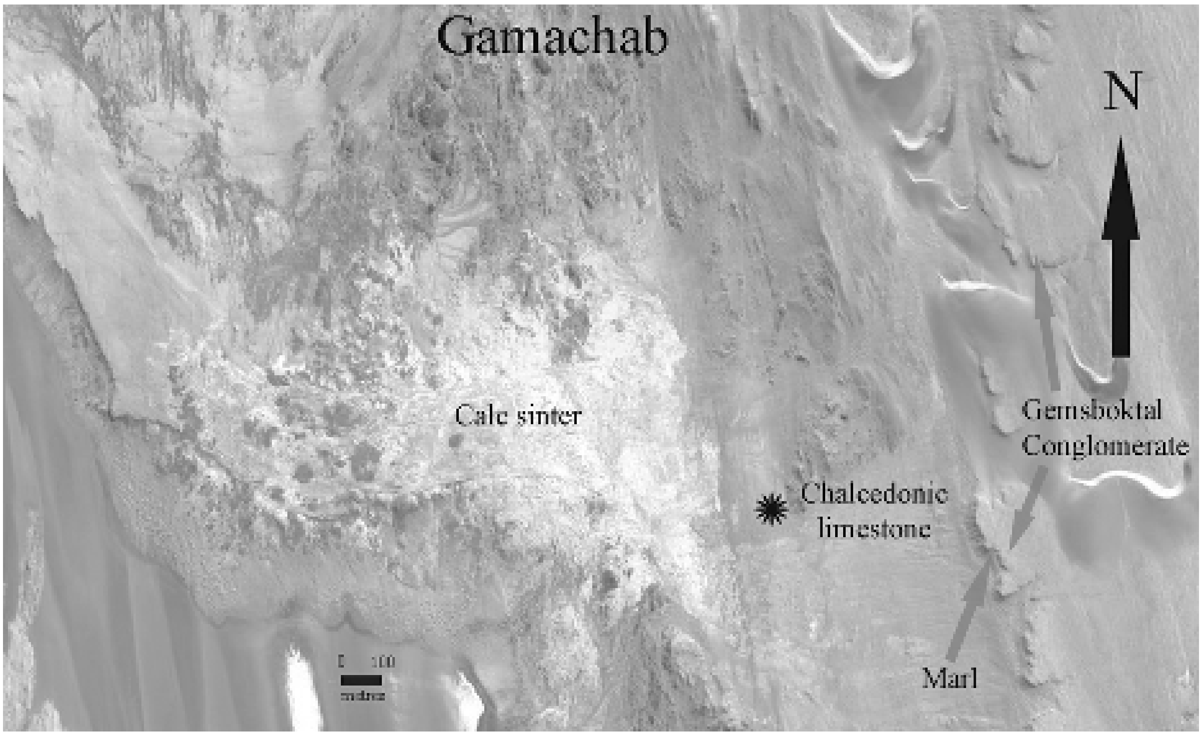

Figure 12. Satellite image of Gamachab, Northern Sperrgebiet, Namibia, modified from Google Earth.

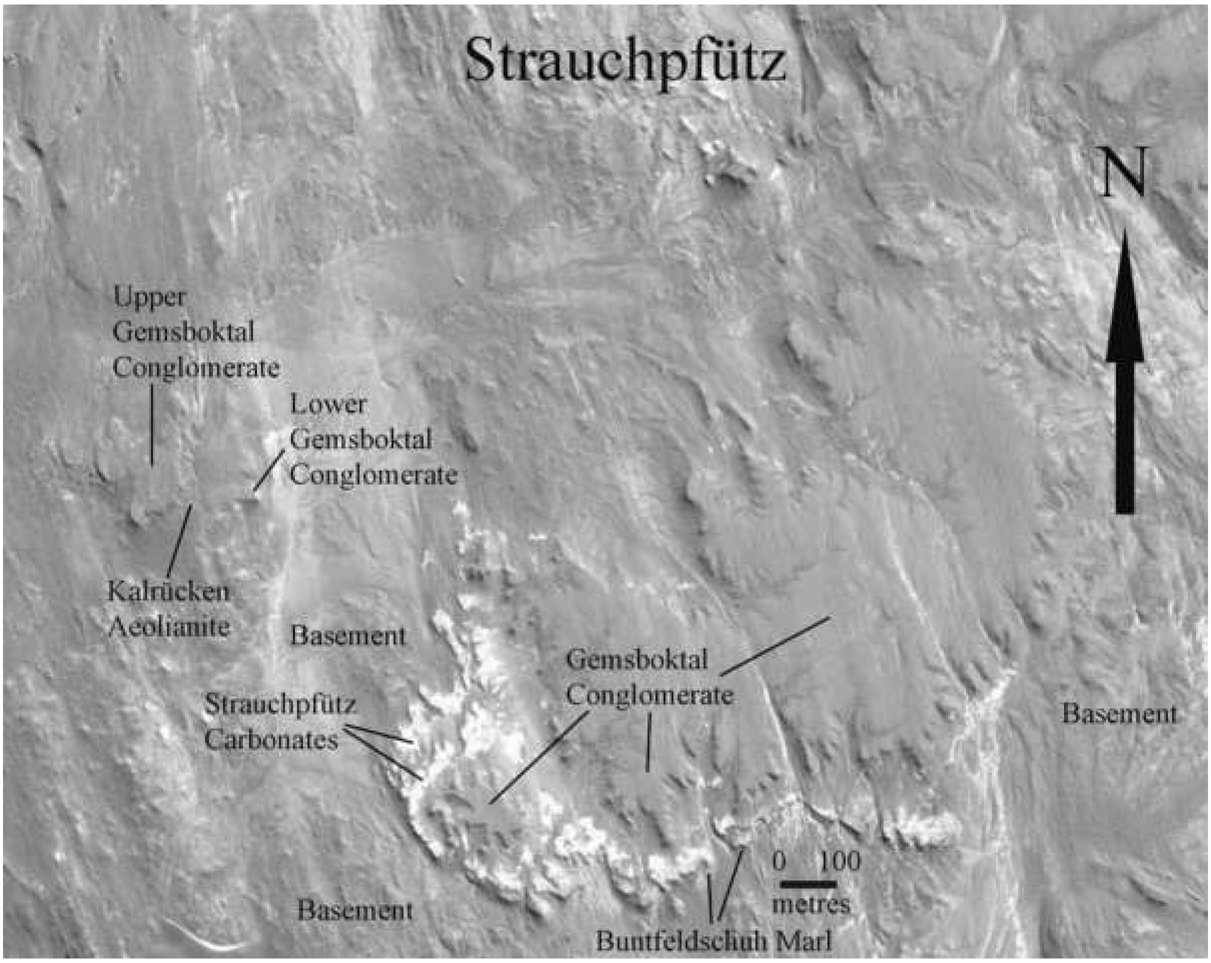

Figure 13. Satellite image of Strauchpfütz, Northern Sperrgebiet, Namibia, modified from Google Earth.

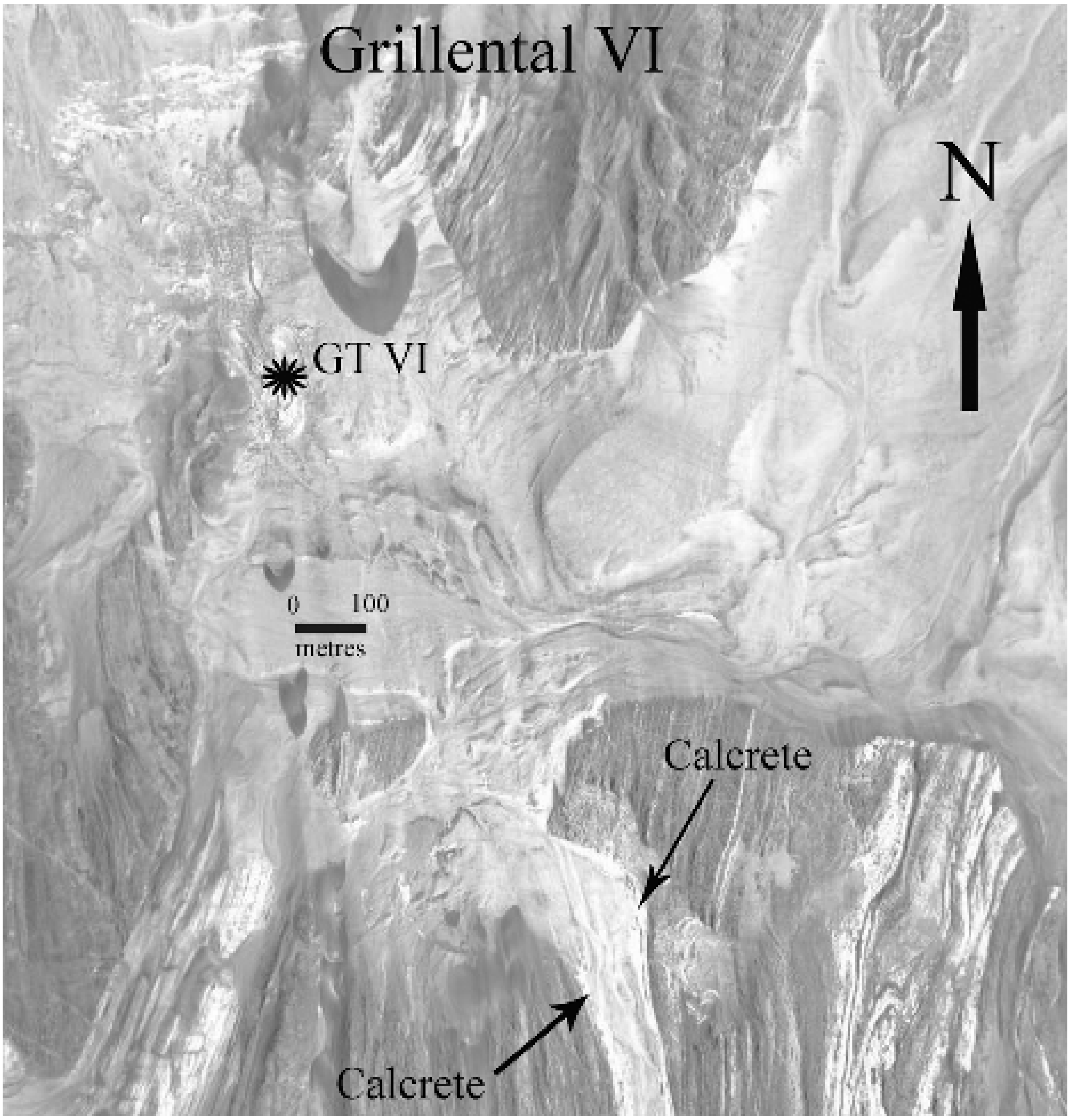

Figure 14. Satellite image of Grillental, Northern Sperrgebiet, Namibia, modified from Google Earth.

derived from them. Thus, the discovery of mammals in these carbonates is important as it will provide detailed age estimates from the deposits themselves. Preliminary identifications of the fossil mammals indicate a preponderance of hyracoids, rodents, a carnivoran and a small primate. The material is still being prepared from the matrix, which will take some time.

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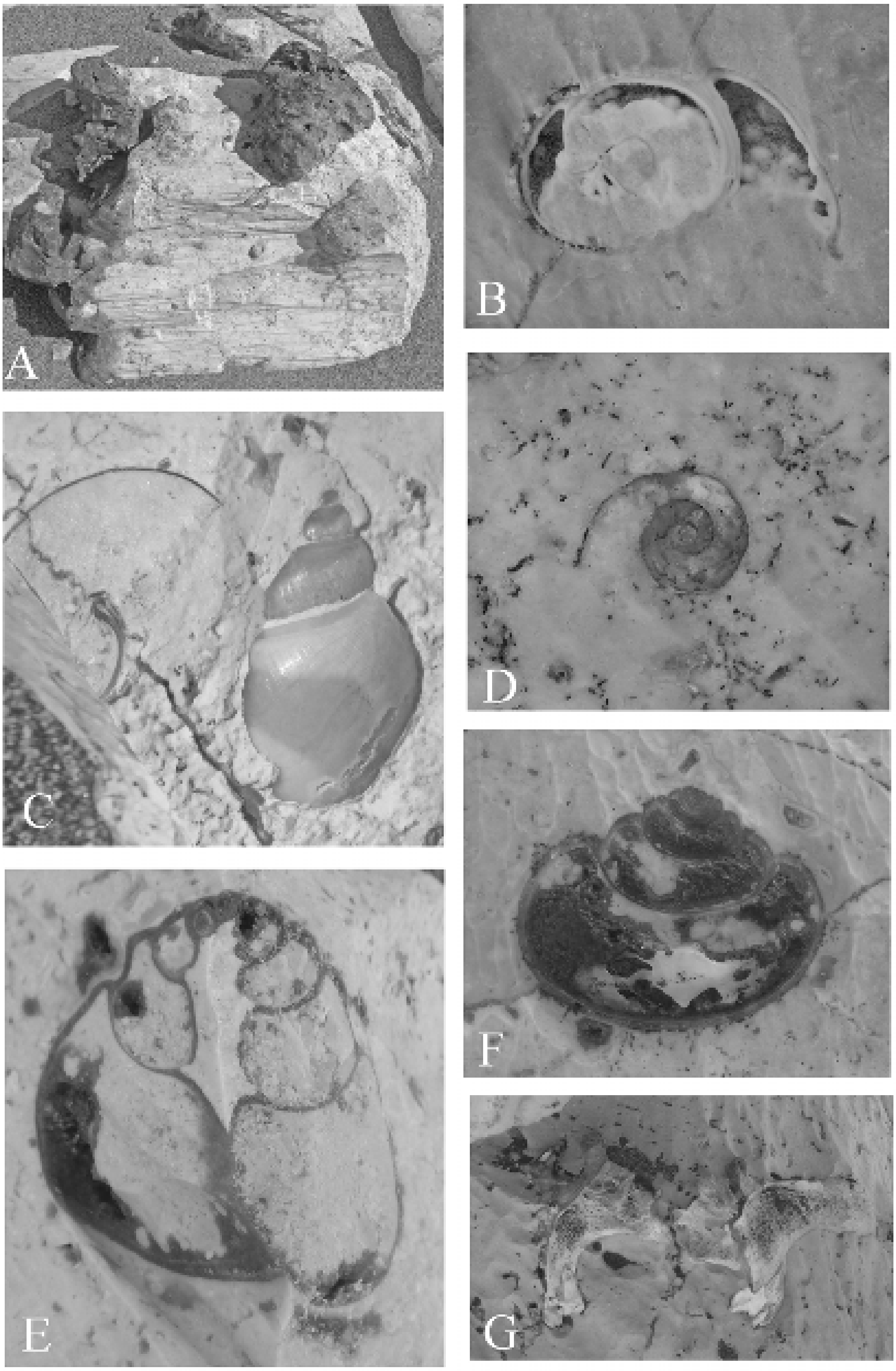

Plate 1. Fossils from carbonate deposits of the Northern Sperrgebiet, Namibia. A) *Lymnaea* sp. in limestone containing nodular chalcedony, Silica North, diameter of block ca 20 cm; B) *Dorcasia* sp. in limestone, Silica South, diameter of snail ca 5 cm; C) *Lymnaea* sp. in limestone from Silica South, height of snail ca 3 cm; D) Planorbid snail in limestone, Silica South, diameter of snail ca 2 cm; E) *Trigonephrus* sp. Black Crow Carbonate, height of shell ca 4 cm; F) *Dorcasia* sp. in Black Crow Carbonate, diameter of shell ca 5 cm; G) Embrithopod skull in Black Crow Carbonate, diameter of skull ca 20 cm.