PALAEONTOLOGICAL IMPACT ASSESSMENT: DESKTOP STUDY

Proposed limestone quarry on Portion 1 of East of Gous Kraal No. 257, Cacadu District, Eastern Cape

John E. Almond PhD (Cantab.)
***Natura Viva* cc, PO Box 12410 Mill Street,**
Cape Town 8010, RSA
naturaviva@universe.co.za

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1. SUMMARY

The proposed new limestone quarry north of Mount Stuart (Steytlerville area, Eastern Cape) will entail shallow excavations into potentially fossil-bearing mudrocks of the Early Permian (278 Ma) Whitehill Formation. The most important fossils likely to be found here include aquatic mesosaurid reptiles, primitive bony fishes and crustaceans. However, the overall impact of the development on palaeontological resources is likely to be minor since unweathered bedrock is unlikely to be exploited and the planned quarrying activities are both small-scale and short-term. Further specialist palaeontological mitigation is therefore not recommended. Should fossil remains be encountered during excavation, however, the material should be safeguarded and SAHRA or a local museum be contacted for advice by the responsible ECO.

2. INTRODUCTION & BRIEF

S.A. Lime (Eastern Cape) (Pty) Ltd are proposing to quarry limestone for agricultural lime on Portion 1 of the farm East of Gous Kraal No. 257, situated *c.* 25km northwest of Steytlerville in the Eastern Cape (Ikwezi Magesterial Area, Cacadu District). The new quarry will be located on the west side of the R338 and some 3 km north of the hamlet of Mount Stuart (Fig. 1). It will be in operation for about five months and will only involve an area of 150m X 100m. An existing quarry that has been operated by PPC since 1965 is situated on the opposite side of the R338 road.

The quarry area is underlain by potentially fossiliferous sediments of the Whitehill Formation (Ecca Group). A desktop palaeontological impact assessment for the project if therefore required by SAHRA in accordance with the requirements of the National Heritage Resources Act, 1999. This study was accordingly commissioned on behalf of the client by Mr Rudi Gerber of Algoa Consulting Mining Engineers.

3. GEOLOGICAL BACKGROUND

As shown by the 1: 250 000 scale geological map 3324 Port Elizabeth and satellite images, the study area lies close to the axis of a WNW-ESE syncline in marine sediments of the lower Ecca Group (Fig.1). The S.A. Lime quarry will be excavated into superficial weathered bedrock belonging to the **Whitehill Formation**. This is a thin (*c.* 20-30 m) succession of finely-laminated, carbon-rich pyritic mudrocks of Early Permian (Artinskian) age that forms part of the lower Ecca Group (Karoo Supergroup). In addition to mudrocks, thin cherts, volcanic tuffs (ash bands) and large dolomitic concretions also occur (Toerien & Hill 1989, Johnson & Le Roux 1994). These Whitehill sediments were laid down about 278 Ma (million years ago) in an extensive shallow, brackish to freshwater basin – the Ecca Sea – that stretched across southwestern Gondwana, from southern Africa into South America (McLachlan & Anderson 1971, Oelofsen 1981, 1987, Visser 1992, 1994, Cole & Basson 1991, Johnson *et al.* 2006). Iron sulphides (pyrite or fools' gold) originally precipitated within the oxygen-poor muds on the floor of the Ecca Sea weather under near-surface conditions to form the whitish mineral limestone which is of economic value both in agriculture and the cement industry.

In the study area fresh Whitehill bedrock (black in colour due to its high carbon content) is covered by a thin cover of soil and pale, deeply-weathered mudrocks. The latter contain the limestone deposits that are to be exploited commercially.

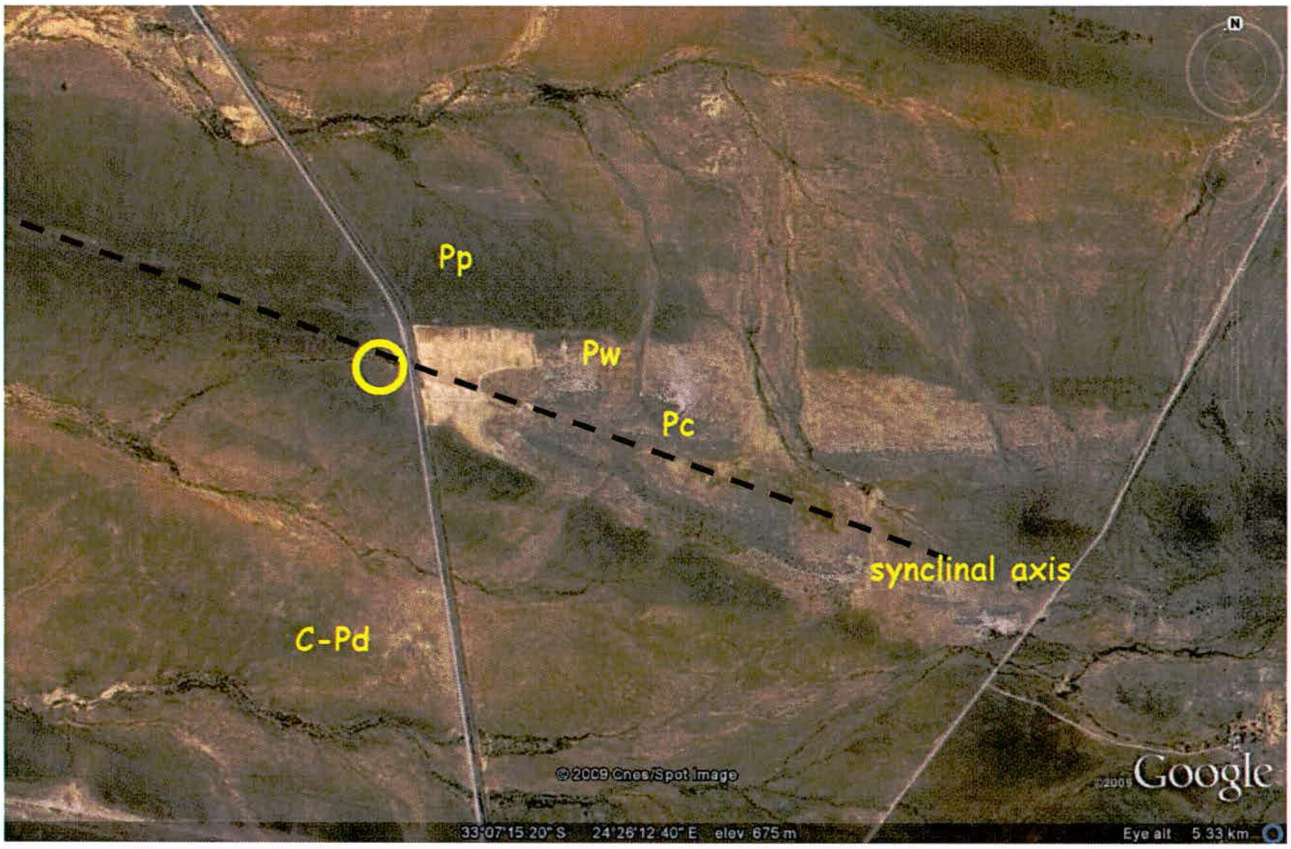

FIG.1. Google satellite image of the study area *c.* 3km north of Mount Stuart, Eastern Cape showing position of proposed new limestone quarry on farm East of Gous Kraal 257 (yellow circle). Geological units indicated are Dwyka Group (C-Pd), Prince Albert Formation (Pp), Whitehill Formation (Pw, pale outcrop), Collingham Formation (Pc).

4. PALAEONTOLOGICAL HERITAGE

In palaeontological terms the Whitehil Formation is one of the richest and most interesting stratigraphic units within the Ecca Group. The overall palaeontological sensitivity of this formation has been rated elsewhere as very high (Almond & Pether 2008). In brief, the main groups of Early Permian fossils found within the Whitehill Formation include:

- aquatic **mesosaurid reptiles** (the earliest known sea-going reptiles)
- rare **cephalochordates** (ancient relatives of the living lancets)
- a variety of **palaeoniscoid fish** (primitive bony fish)
- highly abundant small **eocarid crustaceans** (bottom-living shrimp-like forms)
- **insects** (mainly preserved as isolated wings, but some intact specimens also found)
- a low diversity of **trace fossils** (*eg* king crab trackways, possible shark coprolites / faeces)
- **palynomorphs** (organic-walled spores and pollens)
- **petrified wood** (mainly of primitive gymnosperms, silicified or calcified)
- other sparse **vascular plant remains** (*Glossopteris* leaves, lycopods *etc*).

Important material of the fossil groups listed above has mainly been collected in the Western Cape Province during the twentieth century by a series of palaeontologists (See, for example, McLachlan & Anderson 1971, Oelofsen 1981, 1987, Almond 1996, 2008, Almond & Pether 2008, Evans 2005, and refs. therein). The fossil record of the Ecca Group as a whole in the Eastern Cape is still poorly recorded, mainly comprising isolated reports of vascular plant fragments, mostly unidentifiable, and various trace fossils which may be locally abundant (*eg* Haughton 1928, 1935, Johnson 1976, pp225-226). Note that in the earlier geological literature the Whitehill Formation or "Witband" was included within the Upper Dwyka Shales.

The biostratigraphic distribution of the most prominent fossil groups – mesosaurid reptiles, palaeoniscoid fishes and notocarid crustaceans – within the Whitehill Formation has been documented by several authors, including Oelofsen (1987), Visser (1992) and Evans (2005). A non-technical illustrated account of the fossil biota of the Ecca Sea is given in Appendix 1 (See also MacRae 1999).

5. CONCLUSIONS & RECOMMENDATIONS

The Whitehill Formation bedrock to be exploited in the proposed quarry is potentially fossiliferous. Any fossil remains found during excavation would be of scientific interest, especially given the sparse current knowledge of Ecca Group palaeontology in the Eastern Cape Province as a whole. Therefore any fossils encountered during fresh bedrock excavations made for this development should be safeguarded by the responsible ECO. SAHRA or a local museum (*eg* the Albany Museum, Grahamstown) should be contacted for advice at the earliest opportunity.

It is concluded, however, that pending further discoveries the proposed development will not have a significant impact on local fossil heritage resources given:

- the shallow nature of the excavations (focussing on weathered, limestone-rich bedrock)

- the small area involved (100 x 150 m)
- the short time scale of the operation (*c.* 5 months)

No further palaeontological mitigation is therefore recommended for this project.

6. ACKNOWLEDGEMENTS

Mr Rudi Gerber of Algoa Consulting Mining Engineers is thanked for commissioning this study and for kindly providing the necessary background information.

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Appendix 1: COOL SOUTHERN SEAS OF THE ECCA GROUP, SOUTH AFRICA

JOHN E. ALMOND (2008) *Natura Viva* cc, CAPE TOWN
naturaviva@universe.co.za (021-462 3622)

1. GEOGRAPHY AND CLIMATES IN THE EARLY PERMIAN PERIOD

300 million years ago, at the end of the Carboniferous Period, Gondwana was partially submerged beneath extensive ice sheets, one or more kilometres thick, comparable to those of modern Antarctica. Glacial deposits formed when these massive ice sheets melted – the famous Dwyka *tillites* - outcrop today round the margins of the Great Karoo and very similar sediments are found on all Gondwana continents.

Early in the following Permian Period (290 Ma = Sakmarian Stage) the great Gondwana Glaciations finally, and quite suddenly, came to an end. Cool, shallow seas flooded the margins of Gondwana which were still depressed from the weight of ice sheets. During this period the Karoo Basin - a huge region of subsiding crust in the interior of southwestern Gondwana – was forming. A succession some 10km thick of glacial, shallow marine and continental sediments were later deposited within this basin over a time span of about 100 million years (*c.* 290-182 Ma). The Karoo Basin is famous worldwide for its fossil record of terrestrial tetrapods (amphibians, reptiles, therapsids, early dinosaurs and mammals) of Late Palaeozoic – Mesozoic age (Permian – Jurassic Periods) as well as for its sedimentary and fossil record of the Permo-Triassic Mass Extinction Event.

Around this time a series of collisions between Gondwana and other continental blocks led to the formation of a new, even larger supercontinent called **Pangaea** (Greek" "all land"). Gondwana now formed the southern portion of Pangaea (Fig. 1). The Southern African region lay embedded within Gondwana / Pangaea at high southern palaeolatitudes – estimated at around 60-65ºS in the Early Permian Period.

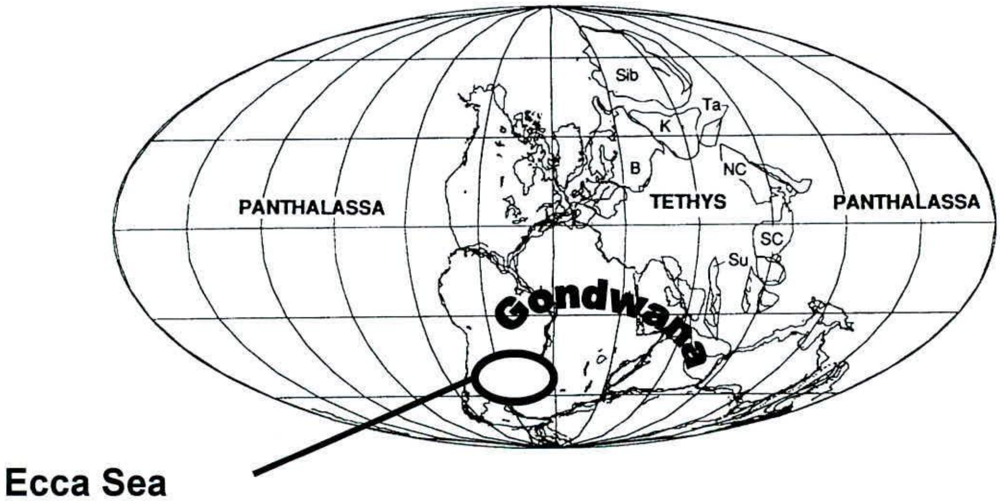


Fig. 1. Palaeogeographic position of the Early to Mid Permian Ecca Sea on Gondwana

In Early Permian Period the Southern African region and adjacent parts of South America - both important parts of SW Gondwana - were covered by the extensive but shallow **Ecca** or

Mesosaurus Sea (Fig. 2). This had a limited connection with the world ocean (**Panthalassa**) in the SW and probably also in the east – narrow seaways. Initially seawater was saline, normal salinity, but gradually became brackish and then freshwater due to input from river systems into the restricted basin. A good modern analogy for the Ecca Sea is the huge but shrinking Caspian Sea in Asia.

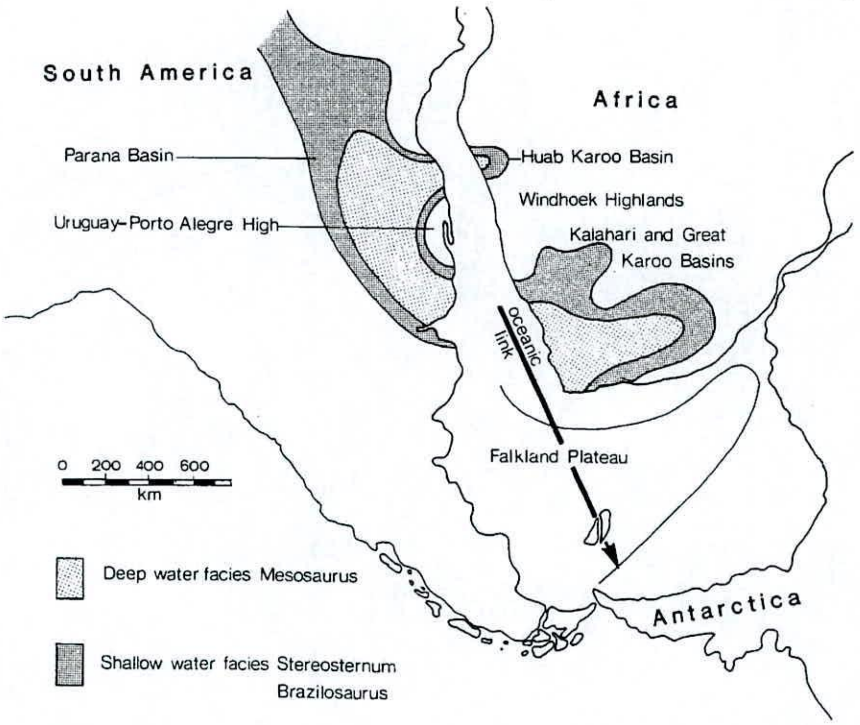


Fig. 2. Geographical extent of the Mesosaurus of Ecca Sea in SW Gondwana

Following the global icehouse conditions of the Carboniferous Period in Gondwana, the Permian was an interval of increasing global warming, culminating in the extreme – and biologically catastrophic - greenhouse conditions at the Permian / Triassic boundary. Climates in the Early Permian Period were still cool temperate, probably with valley glaciers in mountainous uplands such as the so-called Cargonian Highlands of the Northern Cape region, the youthful Cape Fold Belt, as well as volcanic island arc systems off the southern edge of Pangaea. Climates in the Karoo Basin were highly continental, with strongly-marked seasons, as a consequence of its position at high palaeolatitudes within the supercontinental interior, far from the softening influence of the coast. Winters were cold and dark, while summer were long and hot. The presence of several extensive lake systems, including the Ecca Sea itself, in the region may have moderated climatic extremes.

Deposits offshore of fine muds in the young Ecca Sea (*eg* Whitehill Formation, c. 278 Ma = Artinskian Stage), are jet-black in colour and very rich in fine carbon particles (up to 14%). Equivalent sediments in South America (known as the Irati Formation) are mined commercially as oil shales. Extensive blooms of freshwater algae, promoted by high rates of nutrient influx from surrounding continental areas, are probably responsible for the buried carbon. The constant rain of dead algal cells onto the seafloor used up all available oxygen at the sediment /water interface and below. The bottom waters were therefore *anoxic* (oxygen-poor) much of the time, excluding complex animal life, and the sediments are rich in the golden-yellow mineral iron pyrites ("fools gold") that only forms in the absence of oxygen. Corpses of fish, aquatic reptiles and invertebrates which landed on the sea bed were very often preserved intact because of the lack of aerobic decomposers, scavengers and burrowing organisms which might otherwise have disturbed their remains

2. ECCA SEA FAUNA

By 278 million years ago, the Ecca Sea was essentially a huge inland freshwater lake. The variety of animal life living in this water body was limited compared with true marine waters. This was probably due to the high, cool palaeolatitudes (seasonally low primary production and low temperatures) as well as the low salinity. Large populations of small **crustaceans**, rather like modern *krill*, thrived at times within the water column as well as on the bed of the Ecca Sea. Their skeletons, flattened by burial pressure to paper-thinness, cover some bedding planes in their thousands (Fig 3s). Beautiful specimens of intact **palaeoniscoids** - primitive bony fish with an external armour of thick, interlocking scales – are also found (Fig 3b). These fish may have fed on crustaceans and other invertebrates. A wide range of **trace fossils** show that the Ecca Sea was inhabited by many other animals whose skeletal remains have not been preserved. These traces include many different sorts of feeding burrows, fish and amphibian swimming and resting trails (Fig. 3c), and the trackways of small arthropods such as crustaceans and king crabs (Fig. 3d). Rare specimens of fossil insects, including whole animals as well as isolated wings, that were blown offshore from the shores of the Ecca Sea have also been found.

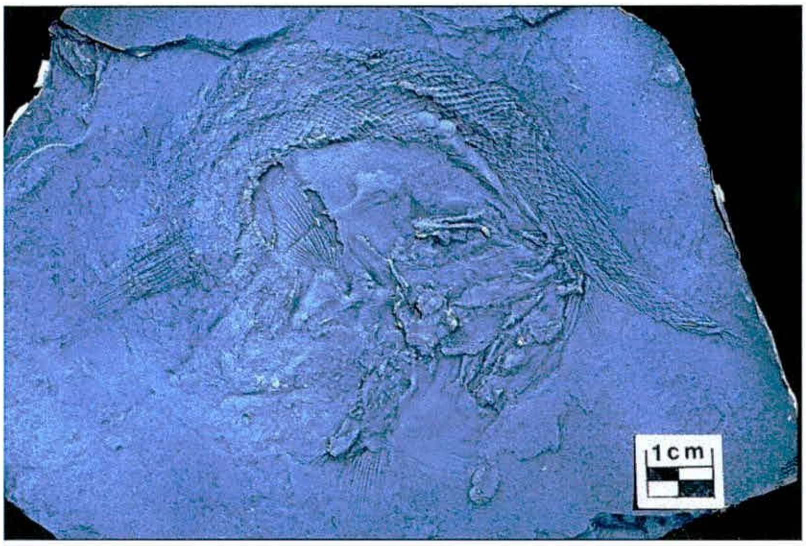


Fig. 3. Ecca Sea fauna:

a. *Notocaris* crustaceans

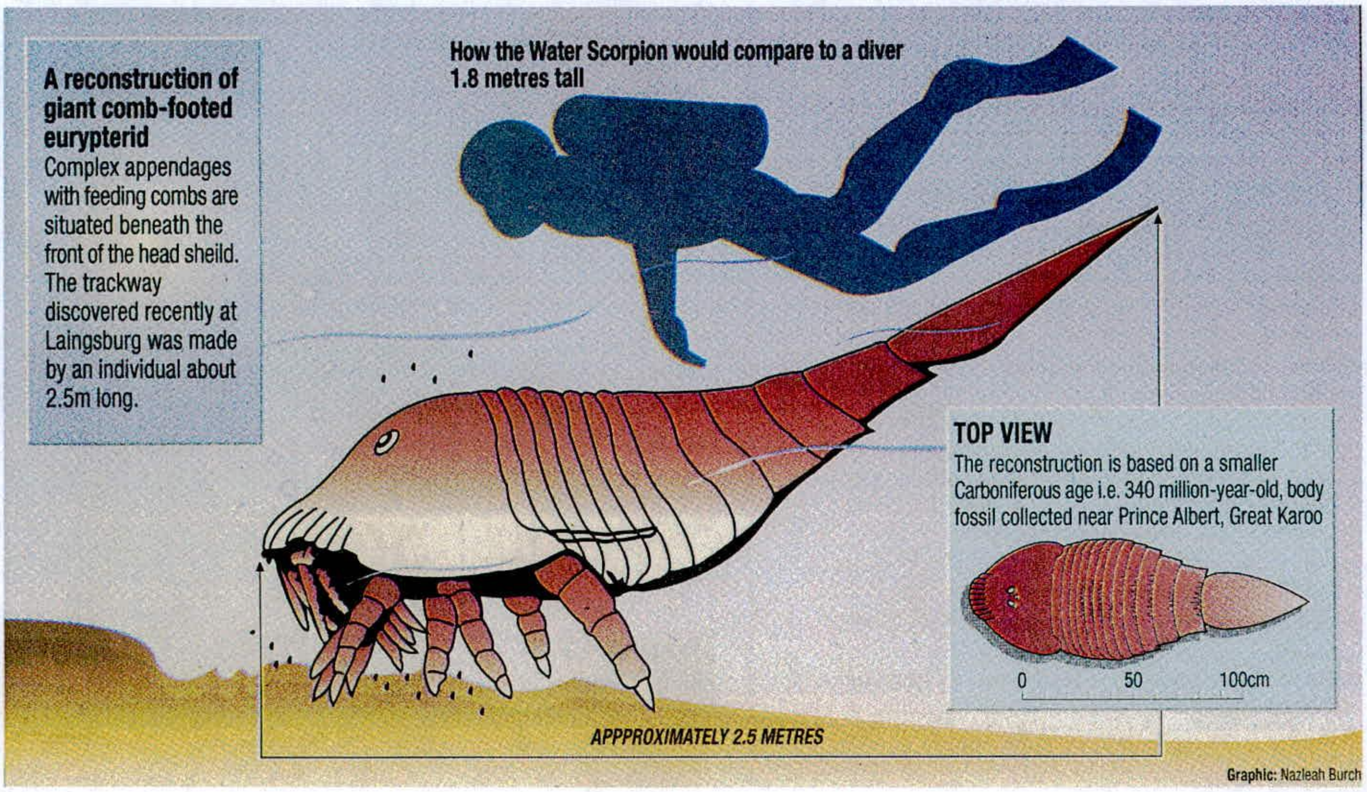
b. Palaeoniscoid fish

c. King crab trackway

d. Large amphibian resting trace on sandrippled lake margin

Giant water scorpions (eurypterids)

The largest animals known from the Ecca Sea were huge **eurypterids** or water scorpions which reached lengths of two metres or more – the largest arthropods ever known. These "gentle giants" were predators but specialised in sweeping up small invertebrates and organic detritus on the seafloor using comb-like structures on their walking legs (Fig. 4). Distinctive trackways and brush-marks made by giant sweep-feeding eurypterids as they simultaneously walked and fed on the Ecca seabed have recently been found near Laingsburg in the SW Karoo (Fig. 5).



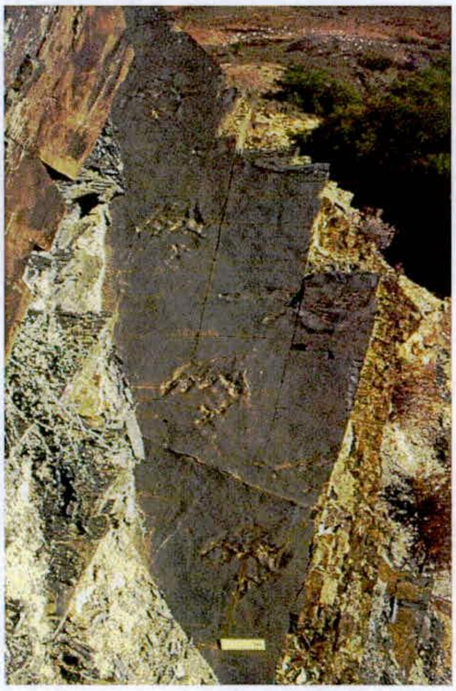


Fig. 4. Artist's reconstruction of a giant sweep-feeding water scorpion (eurypterid) on the Ecca seabed.

Fig. 5. Combined walking and sweep-feeding trackway of a sweep-feeding eurypterid, lower Ecca Group.