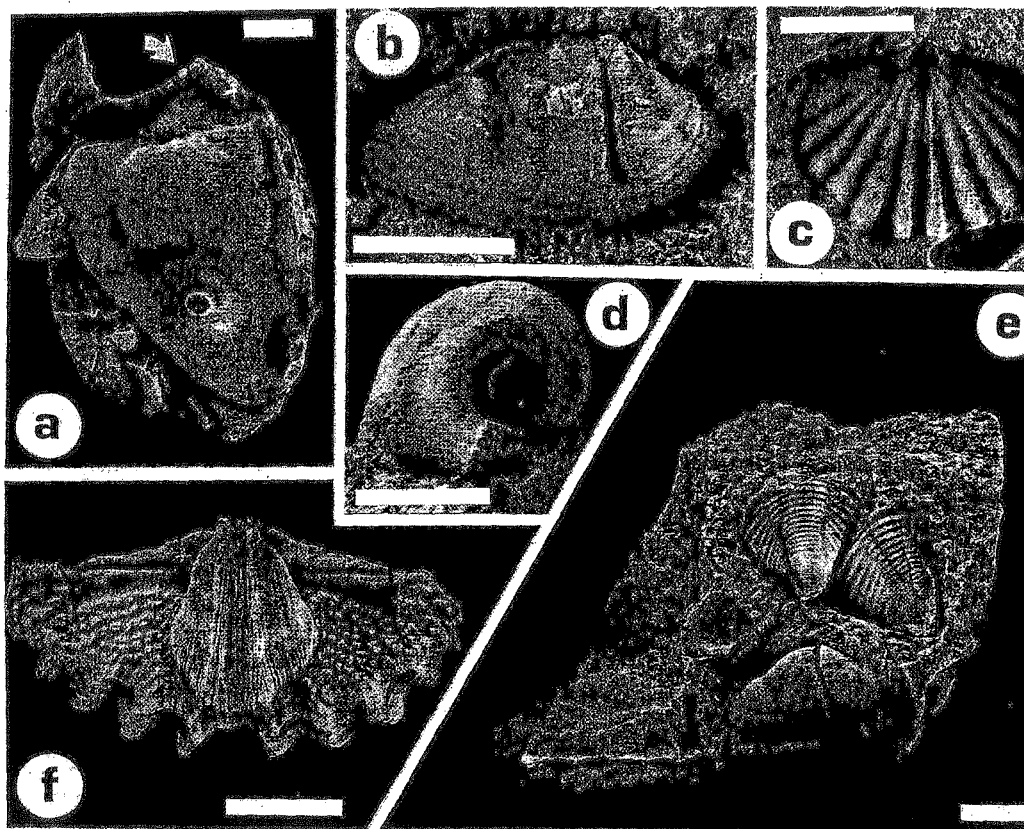


Rec 25/6/08

HERITAGE WESTERN CAPE
Interim Technical Report (May 2008)

PALAEONTOLOGICAL HERITAGE OF THE WESTERN CAPE



Marine invertebrates from the Bokkeveld Group, Early Devonian Period

JOHN ALMOND

Natura Viva cc, PO Box 12410 Mill Street, CAPE TOWN 8010
(naturaviva@universe.co.za)

&

JOHN PETHER

Consultant: sedimentology, palaeontology, stratigraphy, Kommetjie
7976 (jpether@iafrica.com)

PALAEONTOLOGICAL HERITAGE OF THE WESTERN CAPE: INTERIM REPORT

John Almond & John Pether (May, 2008)

Southern Africa can claim a better fossil record than any of the other southern hemisphere continental regions, all of which were once part of the huge Supercontinent Gondwana. The Western Cape in particular enjoys the richest and most diverse palaeontological heritage of all our provinces. Fossils such as Devonian shells from the Bokkeveld Group at Montagu, Swellendam and the Cederberg, or Karoo vertebrates from the Beaufort West area have been recorded here from the early 1800s. However, they were clearly noticed and even collected by San hunter-gatherers long before this, as shown by fossil specimens found at archaeological sites. Cape fossils range from microscopic pollens and spores, leaves and petrified wood, trace fossils preserving the behaviour of extinct animals (*eg* trackways, burrows) and the shells of invertebrates to the isolated teeth and bones, or even intact skeletons of vertebrates such as fish, reptiles and mammals. Professionals involved with heritage management should note that conservation-worthy fossils are found widely outside the better-known occurrences in the Great Karoo and coastal areas.

The Western Cape is the fourth largest province in South Africa, representing some 10.6% of the total area of the RSA (*c.* 130 000 km² - about the same size as Greece or England). The population is approximately 4.8 million and sparsely distributed outside the major urban areas (average density 35 /km²). The province is very diverse in topographic terms, major subdivisions including the Coastal Plain, Cape Fold Mountains, Great Karoo, Great Escarpment and Interior Plateau. Climates are semi-arid and Mediterranean, especially in the west, and due to sparse vegetation and soil cover rock exposure is often good, especially in more arid areas.

Tourism, including ecotourism, is a very important component of the Western Cape economy, but hitherto little advantage has been taken of the region's rich geological and fossil heritage. Notable exceptions include the West Coast Fossil Park at Langebaan Weg near Saldanha, the Fossil Trail at the Karoo National Park, Beaufort West, and the Cango Caves near Oudtshoorn. Major Provincial and National Museums that house important fossil collections from the Western Cape include Iziko: South African Museum (Cape Town), Bernard Price Institute for Palaeontology, Wits (Johannesburg), the Transvaal Museum (Pretoria), the Council for Geoscience (Bellville and Pretoria) and the Geology Department, Stellenbosch University. Local museums and institutions with smaller fossil collections also exist, for example at Prince Albert, Ceres, Montagu and the Karoo National Park (Beaufort West).

Threats to palaeontological heritage in the Western Cape are concentrated mainly along the coast and take the form of rampant coastal development (*eg* housing, golf courses) and, to a lesser extent, mining for building sand. In the interior mining (*eg* for road and building materials) and other development (*eg* road construction) may adversely affect fossil heritage, but have often played a positive role in providing access to fresh fossiliferous bedrock.

The geological record in the Western Cape is complex and varied, extending back in time for over one billion years (1 Ga). Most of the older rocks are unfossiliferous granites and gneisses forming the basement to younger fossil-bearing sedimentary successions of Late Precambrian and Phanerozoic age (*ie* approximately the last 600 million years when complex multicellular life has thrived on Planet Earth).

- **Precambrian to Mesozoic fossil record**

The oldest fossils recorded in the Western Cape Province are cyanobacterial mounds (*stromatolites*), planktonic algae and burrows made by primitive multicellular animals in shallow seas of the Late Precambrian to Early Cambrian period, some 740 to 550 million years ago (Ma). These key fossils come from the Little Karoo and southern Namaqualand. Excellent outcrops of sedimentary rocks of Early to Mid Palaeozoic age in the Cape Fold Mountains record the history of shallow marine and coastal life at high southern latitudes over a time period of over 150 million years. For much of this time, southern Africa lay close to - or even over - the South Pole! Fossil highlights include well-preserved remains of primitive jawless fish from the Table Mountain Group (440 million years old) as well as rich assemblages of marine shellfish, primitive sharks and armoured fish from the Devonian Period (390 to 360 Ma). Complete fossils of bony fish and 1.5m-long water scorpions from the Carboniferous Period (345 Ma) also occur here. In the Western Cape interior the Great Karoo region is famous worldwide for skeletons of the earliest aquatic reptiles as well as for an unparalleled fossil record of the first complex terrestrial ecosystems of Late Permian age (about 260-250 mya). A fascinating fauna of extinct reptiles, mammal-like reptiles (therapsids), amphibians and fish, together with petrified wood and fossil leaves, has been collected from the Beaufort West area and elsewhere since the 1830s. Bones and teeth of large, lumbering herbivores such as the two-tusked dicynodonts and their sabre-toothed predators, the gorgons, record ancient Karoo wildlife over 30 million years *before* the first dinosaurs evolved! Fossil plants and rare specimens of dinosaurs in Cretaceous sediments of the Little Karoo suggest that much remains to be discovered here about extinct life during the Mesozoic Era.

- **Caenozoic fossil record**

The Caenozoic, otherwise known as the "Age of Mammals", refers to the era of "New Life" that followed the abrupt end of the dinosaurs at the end of the Mesozoic Era, 65 mya. Sediments beneath the coastal plains are the main source of Caenozoic

fossils in the Western Cape region. During this era, the world gradually cooled in steps, with marked fluctuations in sea-level as polar ice caps alternately built up or melted. During "ice ages", coastal rivers incised their courses to the lower sea-level, forming now-buried valleys. Fossil plant material from lignites (immature coals) in these ancient valleys record a time when sub-tropical coastal yellowwood forest extended right around the western Cape coast, about 25 Ma. Still only partly sampled and studied, these fossils provide insight into the early evolution of the Cape Flora. The oldest fossil shell faunas (~16 Ma) are found in rare eroded patches of Miocene marine sediments. More extensively preserved fossil-bearing deposits date to the latest Miocene and early Pliocene, 6-4 Ma. The world-renowned "Langebaanian Fauna" fossil deposits at the West Coast Fossil Park, a phosphate-rock quarry, provide a detailed catalogue of coastal life around that time. This is one of the richest Caenozoic fossil assemblages in the world. Ancient to recent dunes and sandsheets cover much of the marine deposits, also bearing fossils on old buried surfaces and interred in vleis and pan sediments. A succession of coastal deposits in units of various ages extends beneath these to the shoreline and continues offshore beneath the seabed. Mainly consisting of shoreface and beach deposits, the fossil seashells and microfossils tell a tale of changes in coastal currents and temperatures, linked to global climatic developments. In places these strata are more complex and may include river, estuarine, marsh, lagoonal, bay and inner-shelf deposits, each with distinctive fossil fauna and flora.

The interim technical report

A summary of selected palaeontological highlights in the Western Cape is given in Table 1 and many of these are also seen in a southern African context in the accompanying figure. A brief account of the fossil content of all the rock units that are depicted on the 1: 1 000 000 scale geological map of the RSA (Council for Geoscience, Pretoria) is given in Table 2. A colour-coding scheme is used to rank these units in terms of their palaeontological significance (see key at end of table). This scheme is necessarily *provisional*, however, and will need to be modified in the light of discussions with heritage managers and palaeontological colleagues.

Also included here is an A4 geological map of the RSA that indicates the most important onshore rock units within the province and a stratigraphic chart on which these units are highlighted (Both from M.R. Johnson *et al.* 2006 *The geology of South Africa*, published by the Council for Geoscience, Pretoria). There is a chart highlighting the fourteen geological maps at 1: 250 000 scale covering the Western Cape that have been published by the Council for Geoscience, Pretoria. In the final version of this report, tabulations of all significant rock units indicated on these maps, together with an outline of their palaeontological significance will be provided. On the basis of the published geological maps and this technical report heritage

managers should then be able to quickly assess the potential significance of proposed developments and to take appropriate action.

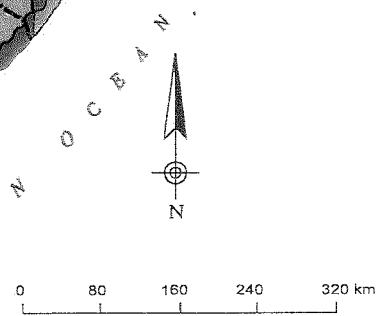
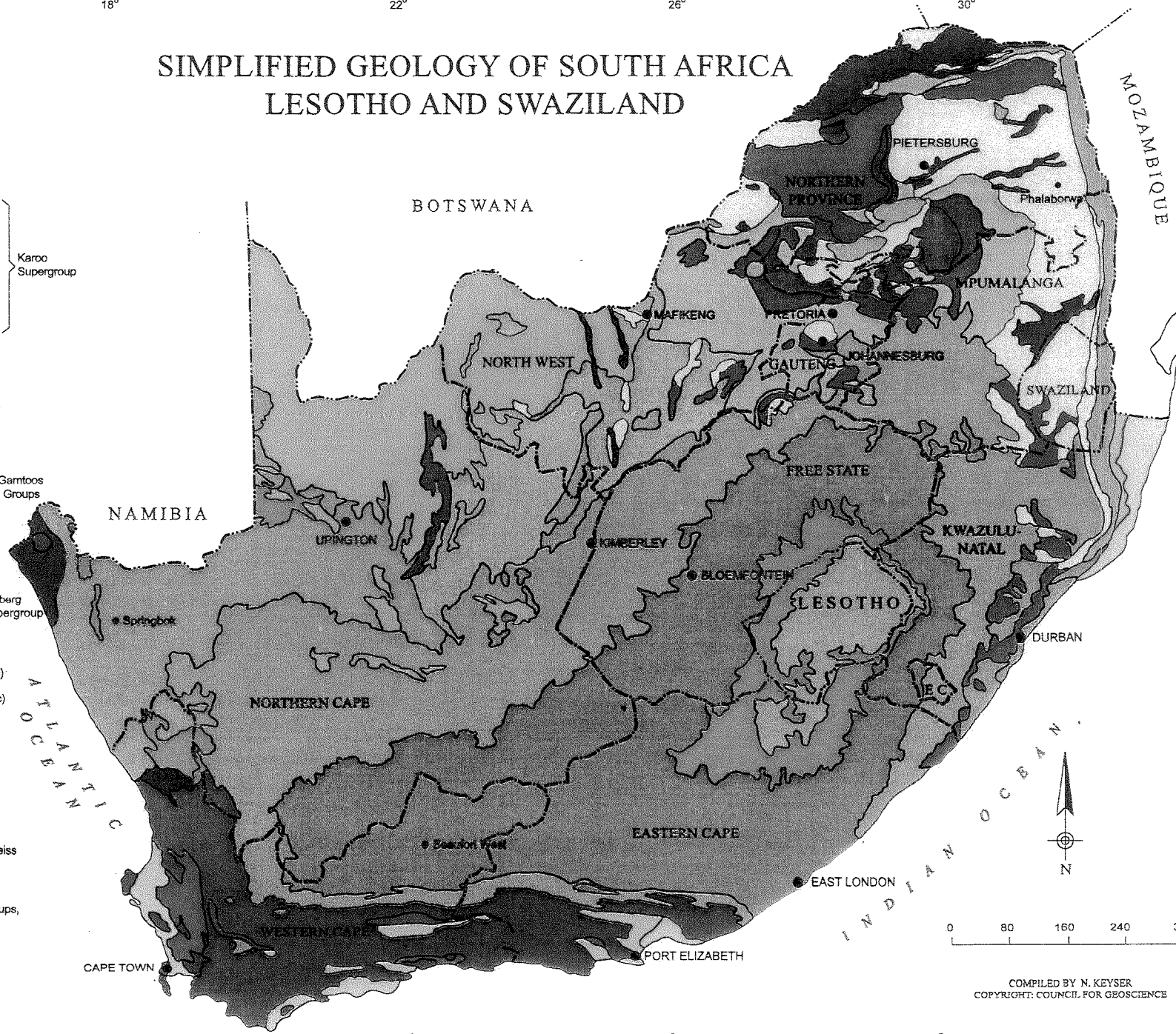
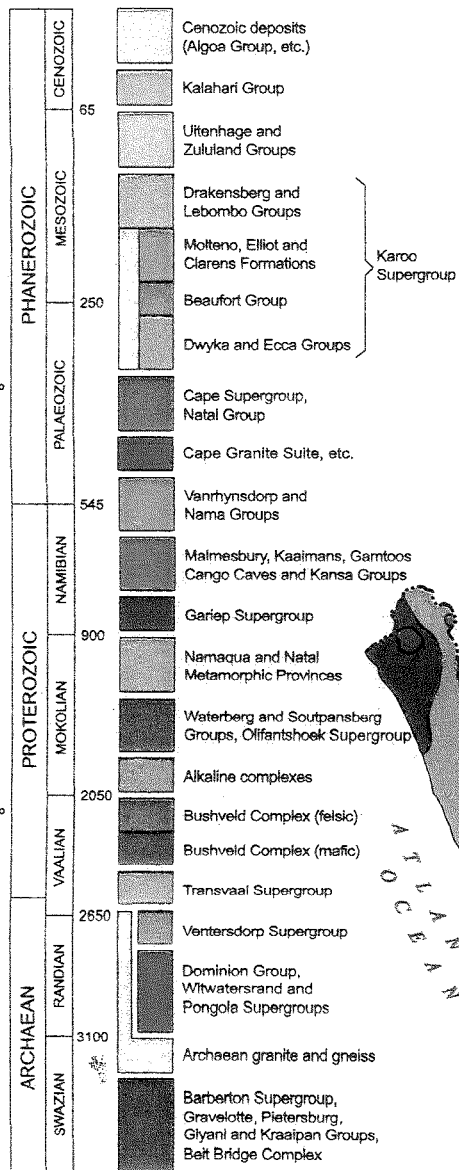
Challenges and opportunities

There is widespread confusion concerning the contrasting nature, distribution and vulnerability of palaeontological *versus* archaeological heritage resources in the minds of the general public, developers and conservation managers alike. Many proposed developments involving excavation into bedrock represent welcome research opportunities for palaeontologists, *provided* that they are given the chance to study and collect fossils *in situ* while fresh sediments are still exposed. Many opportunities for constructive collaboration between palaeontologists and road-builders, miners and developers in the province are currently being lost.

Fossils have a heritage significance beyond their conventional scientific importance. They are part of the physical strata forming the landscape and inform the appreciation of its space-time depth and its biota, living and extinct. Ultimately this heritage resource must be made known and accessible to the wider community *via* educational programmes. The first priority, however, is to rescue fossils and attendant information that would otherwise be irretrievably lost.

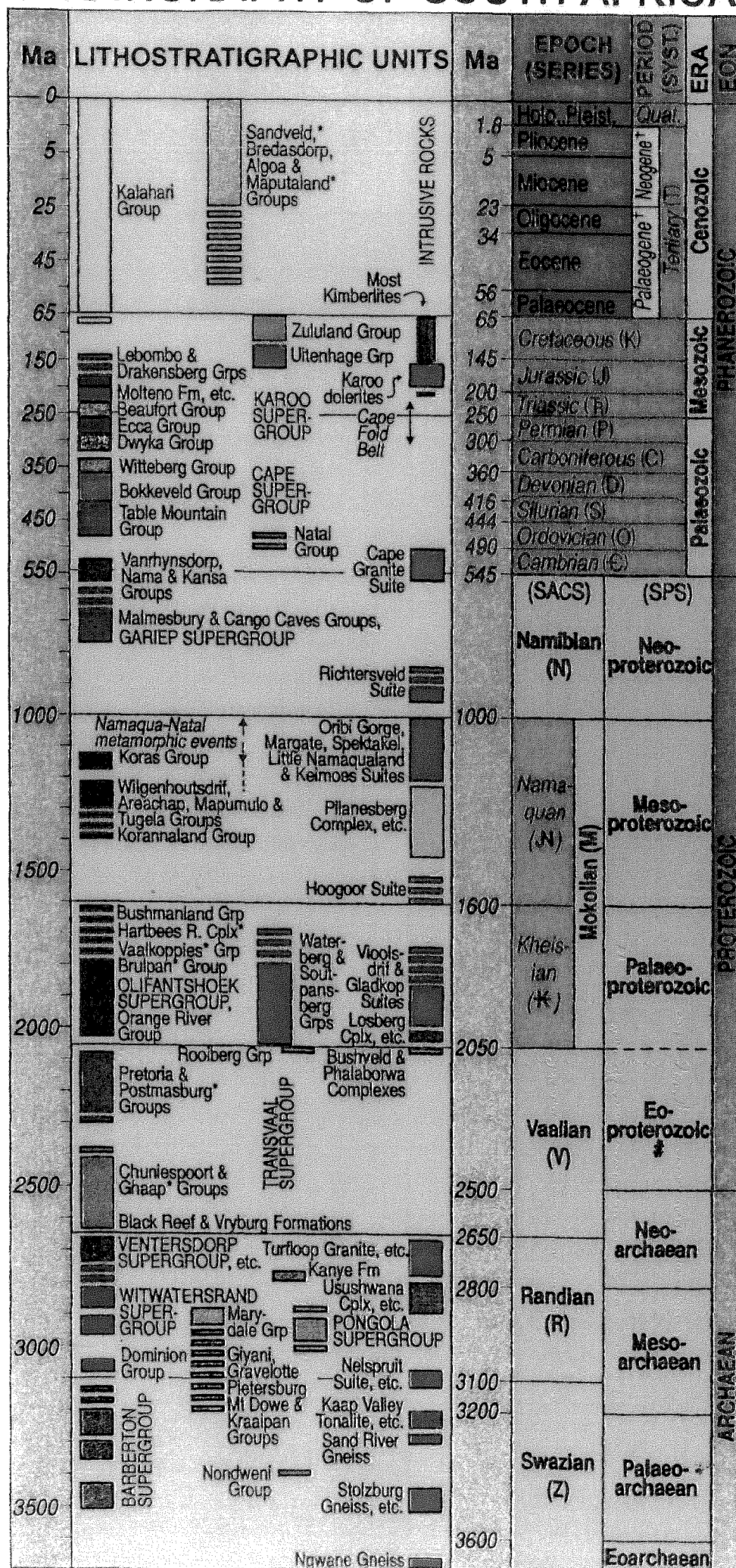
Caenozoic fossils from the Western Cape coast are of national and international scientific importance. Coastal developments provide opportunities to examine and sample this subsurface geological and fossil record. It is vital that these opportunities are seized and the fossils rescued from destruction, as subsequently the information is indefinitely "sealed" beneath properties and structure.

SIMPLIFIED GEOLOGY OF SOUTH AFRICA LESOTHO AND SWAZILAND



COMPILED BY N. KEYSER
COPYRIGHT: COUNCIL FOR GEOSCIENCE

STRATIGRAPHY OF SOUTH AFRICA



* Not yet approved by SACS (Z) Standard CGS map symbol † Subperiod (Subsystem) © CGS 2006
SPS = Subcommittee for Precambrian Stratigraphy # Not ratified by IUGS

**TABLE 1. WESTERN CAPE FOSSIL HERITAGE:
PALAEONTOLOGICAL HIGHLIGHTS**

FOSSIL BIOTA	KEY LOCALITIES / AREAS	PALAEONTOLOGICAL SIGNIFICANCE
Bredasdorp, Sandveld & West Coast Groups. Mainly Pliocene to Quaternary terrestrial mammals, birds & reptiles. Some marine fauna (cetaceans, seals, seabirds)	Marine, estuarine, fluvial and aeolian deposits of coastal plains. Intersects with archaeological record in Quaternary	Generally sparse fossils mainly recording late Caenozoic evolution of terrestrial mammal fauna of Southern Africa, including <i>Homo sapiens</i> . Locally very rich e.g. Langebaanweg
Bredasdorp, Sandveld & West Coast Groups. Miocene to Quaternary fossil mollusca & other marine invertebrates. Also fish	Marine deposits of coastal plains. De Hoopvlei, Klein Brak, Varswater, Velddrif & Alexander Bay Formations.	Locally rich shell faunas recording Caenozoic cooling and evolution of modern marine biotas
Miocene lignites (fossil peats), Bredasdorp, Sandveld and West Coast Groups	Noordhoek Valley (Cape Peninsula), Knysna, Olifants River (Vredendal)	Rich fossil pollen spectra aid reconstruction of Miocene vegetation and climates. Some fossil wood, leaves etc.
Kirkwood Formation dinosaurs (Uitenhage Group), Early Cretaceous	Oudtshoorn Basin	Fragmentary finds of small to large dinosaurs so far, but potential for exciting discoveries in future
Late Jurassic / Early Cretaceous biota of Brenton Formation (Uitenhage Group)	Knysna	Only sizeable marine biota of Mesozoic age in Western Cape
Beaufort Group biota (Karoo Supergroup), Late Permian	Great Karoo proper	Rich terrestrial vertebrate fauna of Late Permian age
Whitehill Formation biota (Karoo Supergroup), Mid Permian	Great Karoo, Tanqua Karoo, Worcester-Robertson Karoo	Exceptionally preserved mesosaurid reptiles, bony fish
Waaipoort Formation biota (Witteberg Group), Early Carboniferous	Southern margin of Great Karoo, Tanqua Karoo	Excellent preservation of fish fossils, giant water scorpions (eurypterids)

Upper Bokkeveld Group / Traka Subgroup biota, Mid Devonian	Cederberg, Little Karoo	High palaeolatitude fish and plants from the Mid Devonian
Lower Bokkeveld Group / Ceres Subgroup biota, Early Devonian	Cape Fold Belt	Diverse marine invertebrates, trace fossils and rare fish from Malvinokaffric Faunal Realm of Gondwana
Soom Member Biota (Cederberg Formation, Table Mountain Group), Late Ordovician	Cederberg, Hex River Mountains	Exceptional soft-tissue preservation in a post- glacial biota, including two groups of primitive jawless fish
Vanrhynsdorp Group trace fossil assemblages and stromatolites, Ediacaran - Early Cambrian	Bokkeveld Escarpment near Vanrhynsdorp, Bitterfontein area	Documentation of metazoan behavioural evolution across the Precambrian / Cambrian boundary
Stromatolites (bacterial mounds) in Cango Caves Group and Gifberg Group, Ediacaran	Little Karoo, Bokkeveld Escarpment	Oldest macrofossils in the Western Cape (c. 550-600 Ma)

FOSSIL HIGHLIGHTS OF SOUTHERN AFRICA - THE LAST 550 MILLION YEARS

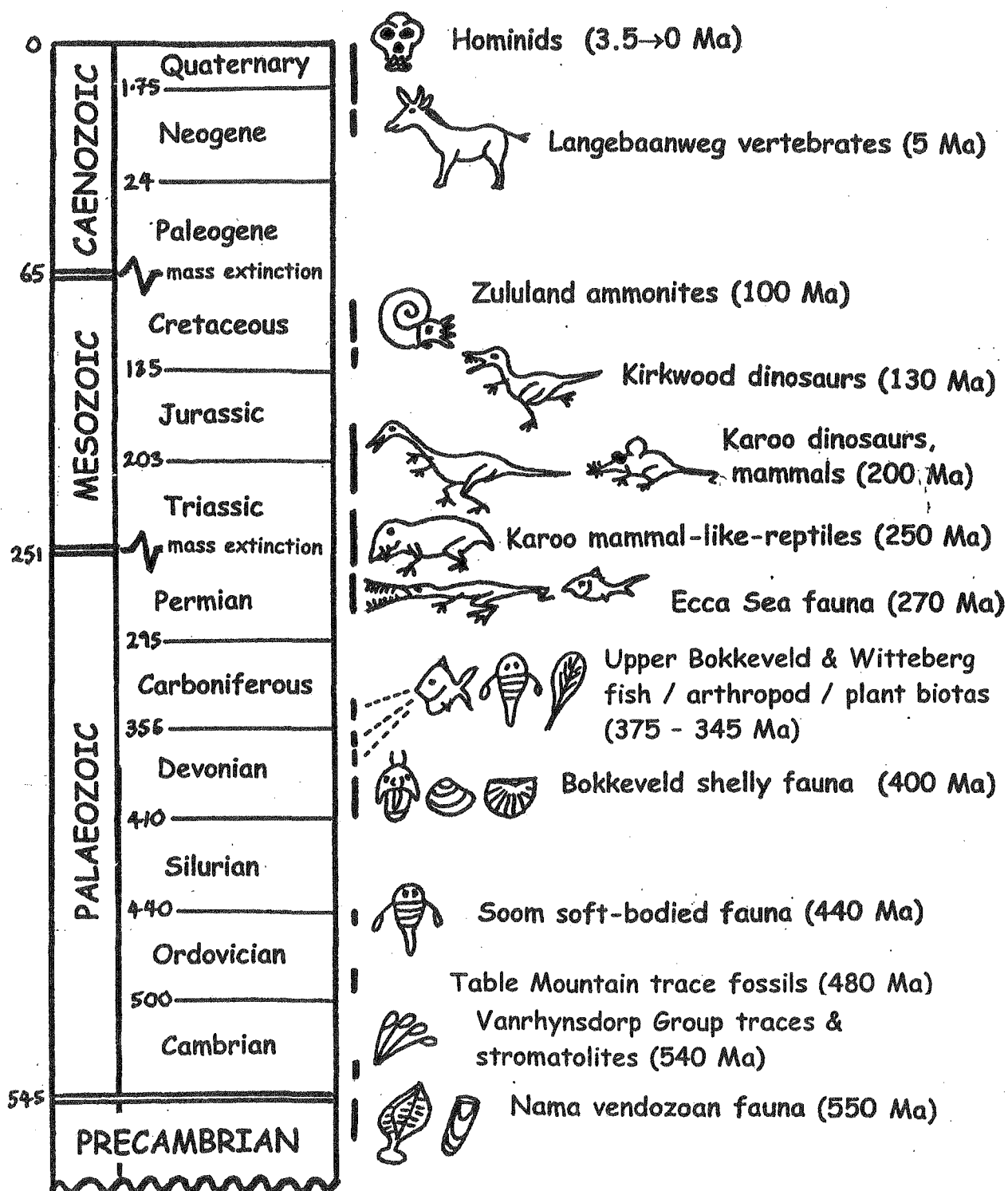


TABLE 2: FOSSIL HERITAGE OF THE WESTERN CAPE

GEOLOGICAL UNIT		ROCK TYPES & AGE	FOSSIL HERITAGE	COMMENTS
COASTAL CAENOZOIC DEPOSITS	WEST COAST GROUP (Q)	<p>Mainly regressive, prograded shallow-marine sequences comprising basal conglomerates overlain by sandy and gravelly shoreface and sometimes foreshore deposits. Estuarine to fluvial deposits occur in vicinities of rivers and locally also muddier, sheltered embayment and lagoonal deposits.</p> <p>The tops of marine sequences are eroded and overlain by aeolianites. Interbedded and capping calcretes and other soil profiles mark stable palaeosurfaces.</p> <p>Lithologies are mainly calcareous in the Bredasdorp and Sandveld Groups and sandier and decalcified in the West Coast Group.</p> <p>The marine deposits have discrete ages associated with high sea-levels and polar-ice melting during globally-warm periods: mid-Miocene ~16 Ma, early Pliocene ~5 Ma, late Pliocene ~3 ma and later Quaternary <1 Ma. Aeolianites of various intervening ages.</p>	<p>In the marine deposits are fossil molluscan seashells, brachiopods, crustaceans (barnacles, crabs, prawns, ostracods), echinoids, polychaete worm tubes, corals, bryozoans & foraminifera. Shark teeth are common, other fish teeth occur. Bones of whales, dolphins, seals & seabirds. Trace fossils made by prawns, worms, echinoids, anemones, bivalves, fish <i>etc.</i>, are pervasive.</p> <p>Bones of land mammals appear in estuarine and lagoonal deposits.</p> <p>In the aeolianites are land snails, tortoises, moles, OES, insect traces. Larger animal bones are sparsely scattered on palaeosurfaces (bovids, zebra, rhino, elephant, pigs <i>etc.</i>). Deposits assoc. with vleis, pans, springs very rich, esp. birds, micromammals, Man!</p>	<p>Marine fossil record is four discrete "time slices" or "windows" into the evolution of the coastal biota during Neogene-Quaternary global cooling, from tropical conditions to those today. Langebaanweg (Fossil Park) a rich sample of land fauna deposited ~5 Ma in estuary: quite possibly other such occurrences on coastal plains.</p> <p>Fossil data associated with aeolian record overlaps with presence of hominids and evolution of <i>H. sapiens e.g.</i> several important coastal archaeological sites (Elandsfonteyn, Duinefontein, Swartklip).</p> <p>Sparse fossil in aeolianites very important for filling gaps in terrestrial faunal record. Potential floral record in vlei deposits.</p>
	SANDVELD GROUP (T-Qs)			
	BREDASDORP GROUP (T-Qb)			

<p>CAENOZOIC DEPOSITS OF THE INTERIOR</p> <p>Q (in part)</p>	<p>ancient to modern alluvium including palaeodrainage systems (<i>eg</i> Karoo River, Olifants River, Kwagga's Kop Formation)</p> <p>pedocretes (<i>eg</i> silcretes, calcretes, ferricretes) <i>eg</i> Grahamstown Formation ((Tg) Miocene or older ?Cretaceous / Palaeocene)</p> <p>cave deposits</p> <p>spring deposits</p> <p>lake / marsh and pan deposits</p> <p>Miocene to Recent</p>	<p>freshwater & terrestrial molluscs, mammal bones (incl. hyaena dens, micromammals in owl pellets), teeth & horn cores, trace fossils (<i>eg</i> calcretised termitaria, rhizoliths, coprolites, gastroliths, ostrich eggs shells <i>etc</i>), vascular plants in pedocretes (<i>eg</i> silcretes) lignites with fossil wood (silicified / carbonised), leaves, pollens of vascular plants, diatoms</p>	<p>Record of changing climates, fauna and vegetation since Gondwana fragmentation. See also archaeological literature for Quaternary - recent fossils (<i>eg</i> Boomplaas, Cango Caves).</p> <p>Important Miocene lignites with wood, pollens in Knysna Formation and Elandsfontyn Formation at Noordoek (Cape Peninsula). Pollens also from Cederberg, Verlorenvlei, Boomplaas <i>etc</i>. Silicified wood from Olifants River gravels, Vredendal (Miocene).</p> <p>Kwagga's Kop Formation of Vanrhynsdorp area (Late Neogene) - unidentified vertebrate remains</p>
<p>VOLCANIC PIPES</p>	<p>volcanic pipes (kimberlites, olivine melilitites)</p> <p>?no crater lake sediments</p> <p>Late Cretaceous / Early Palaeogene (Palaeocene)</p> <p>c. 75 - 55 Ma</p>	<p>no fossils recorded in W. Cape, but these may be present if crater lake sediments are preserved</p>	<p>Important plant and animal fossils (including vertebrates), microfossils (<i>eg</i> spores, pollens) recorded from crater lake sediments in Northern Cape</p> <p>Melilitite pipes / plugs in Heidelberg, Robertson,</p>

				Lambert's Bay & Bitterfontein -Garies areas
UITENHAGE GROUP	Hartenbos Formation (Kb) fluvial sandstones and mudrocks Early Cretaceous		petrified wood common, fossil plants	Overlies Buffelskloof Formation NW of Hartenbos only (Mossel Bay area)
	Buffelskloof Formation (Kb) alluvial fan and fluvial breccio- conglomerates Early Cretaceous		no fossils recorded	
	Kirkwood Formation (J-K) terrestrial (fluvial / lacustrine) siliciclastics Early Cretaceous		variety of small to large dinosaurs (theropods, sauropods, ornithopods), other reptiles, Mesozoic mammals, petrified wood, lignites ("Wood Beds"), leaves (ferns, cycads, conifers), freshwater invertebrates (bivalves, phyllopod crustaceans), fish scales, insects	Undescribed large dinosaur remains from Kirkwood Formation of Oudtshoorn Basin Freshwater invertebrates mainly from Heidelberg area
	Brenton Formation (Je) grey mudrocks, sandstones, subordinate conglomerates, coquinities Late Jurassic (or Early Cretaceous)		marine invertebrates (especially molluscs, including ammonites, also echinoderms, various groups of microfossils eg forams, ostracods), plesiosaur reptile teeth, plant fragments	Only extensive onshore marine succession of Mesozoic age in W. Cape. Variously correlated with lower Sundays River Formation or Colchester Formation of E. Cape

	Robberg Formation (Je) sandstones, minor breccio-conglomerates, shales Late Jurassic (or Early Cretaceous)	casts of marine invertebrates (especially trigoniid and other bivalves, rare ammonites, echinoids), casts of wood and plant debris, coalified plant fragments (cycads, ferns, horsetails, conifers), trace fossils, organic-walled microfossils, coccoliths	Robberg Peninsula, Plettenberg Bay Previously mapped as Enon Possible correlation with Sunday's River Formation of E. Cape
	Enon Formation (Je) conglomeratic, fluvial "red beds" Late Jurassic	transported bone fragments, teeth, coalified wood	Several younger Uitenhage Group formations mapped as Enon on older geological maps
KAROO DOLERITE SUITE Jd	intrusive dolerites, basalts, pipes, hydrovolcanic diatremes Early Jurassic (182 Ma)	NO FOSSILS RECORDED	Crater lake facies not preserved Late Jurassic extinction event attributed to Karoo-Ferrar Large Igneous Province

<p>BEAUFORT GROUP</p> <p>Adelaide Subgroup</p> <p>Pa</p>	<p>continental (fluvial, lacustrine) siliciclastic sediments (sandstones, mudrocks, intraformational breccioconglomerates), pedocretes (calcretes)</p> <p>Late Permian</p>	<p>diverse terrestrial and freshwater tetrapods of <i>Eodicynodon</i> to <i>Dicynodon</i></p> <p>Assemblage Zones (amphibians, true reptiles, synapsids - especially therapsids), palaeoniscoid fish, freshwater bivalves, trace fossils (including tetrapod trackways), sparse vascular plants (<i>Glossopteris</i> Flora, including petrified wood)</p>	<ul style="list-style-type: none"> • richest Late Permian tetrapod fauna from Pangaea / Gondwana • key evidence for evolution of mammalian characters among therapsids • continental record of lead up to Late Permian Mass Extinction Events
---	--	---	--

ECCA GROUP		offshore basinal to coastal deltaic sediments, predominantly non-marine, with minor volcanic ashes. Early - Mid Permian 290 - 266 Ma	non-marine trace fossils, vascular plants (including petrified wood) and palynomorphs of <i>Glossopteris</i> flora, mesosaurid reptiles, palaeoniscoid fish (including microvertebrate remains, coprolites), crustaceans, sparse marine shelly invertebrates (molluscs, brachiopods), microfossils (radiolarians <i>etc</i>), rare insects, rolled tetrapod bones	diverse non-marine trace fossil assemblages from Gondwana exceptionally preserved biota of Whitehill Sea (mesosaurid reptiles, fish, crustaceans, traces, rare plants including petrified wood) giant eurypterid (water scorpion) traces in Collingham Formation
DWYKA GROUP C-Pd		glacial, interglacial and post-glacial siliciclastic sediments (predominantly tillites). Late Carboniferous - Early Permian c. 320-290 Ma	trace fossils, organic-walled microfossils, rare marine invertebrates, fish (sharks, palaeoniscoids), vascular plants (glossopterid leaves, lycopods)	Fossils largely from interglacial and immediately post-glacial sediments
WITTEBERG GROUP	KOMMADAGGA SUBGROUP Dl	glacial and shallow marine siliciclastics Early / Mid Carboniferous	sparse vascular plants, traces, palynomorphs	Witteberg Group provides important record of Late Devonian to Early

	LAKE MENTZ SUBGROUP DI	lacustrine / lagoonal / coastal mudrocks, sandstones, minor conglomerates Early Carboniferous	non-marine fish fauna (palaeoniscoids, sharks, acanthodians), giant eurypterids (water scorpions), vascular plants (<i>eg</i> lycopods, wood), freshwater bivalves, traces, organic-walled microfossils	Carboniferous high palaeolatitude biodiversity and extinction events. Mass mortality fish beds in Waipoot Formation
	WITPOORT FORMATION Dw	shallow marine sandstones, quartzites with minor lagoonal mudrocks, glacial sediments Late Devonian	diverse lagoonal biota of fish (placoderms, sharks, bony fish, lampreys <i>etc</i>), arthropods (<i>eg</i> eurypterids), vascular plant flora, seaweeds, charophytes, traces, microfossils (E. Cape)	The most diverse shelly faunas known from Weltevrede Subgroup are from E. Cape so far. Thick sandstone units (<i>eg</i> most of Witpoort Fm.) are poorly fossiliferous whereas mudrocks are of high palaeontological significance. Witpoort lagoonal biota lived close to Late Devonian South Pole.
	WELTEVREDE SUBGROUP Dw	shallow marine sandstones, mudrocks Mid to Late Devonian	sparse shelly invertebrates (brachiopods, molluscs, rare trilobites), trace fossils, microfossils, rare fish	
BOKKEVELD GROUP Db	4b. TRAKA SUBGROUP Dbi, Dt	shallow marine (deltaic / estuarine?) siliciclastics Mid Devonian	fish (sharks, placoderms, bony fish, acanthodians), vascular plants (lycopods), trace fossils, bivalves, brachiopods, microfossils	Biostratigraphically and palaeoecologically important fossil assemblages from high palaeolatitudes (Klipbökkop and Adolphspoort Formations)

	4a. CERES SUBGROUP Dc	shallow marine siliciclastics Early - Mid Devonian	diverse shelly invertebrate biota (trilobites, molluscs, brachiopods, echinoderms <i>etc</i>) and trace fossils, rare fish remains & plants (lycopods), microfossils	Typical Malvinokaffric Faunal Realm fossil assemblages from cool seas of southern Gondwana
TABLE MOUNTAIN GROUP Op, Ope, Sn		predominantly fluvial sandstones, with subordinate pebbly conglomerates, mudrocks, tillites occasional intervals of shallow marine / coastal sandstones and mudrocks Early Ordovician - Silurian - Early Devonian	organic-walled microfossils expected in mudrock subunits shallow marine / estuarine trace fossils (Graafwater & Peninsula Formations, Nardouw Subgroup) Cederberg Formation contains Soom Biota (Cederberg Formation) of post-glacial marine invertebrates, jawless fish, microfossils <i>etc</i> as well as Disa shelly biota (brachiopods <i>etc</i>) Rietvlei / Baviaanskloof Fm marine shelly faunules (brachiopods, molluscs, rare trilobites, bryozoans <i>etc</i>), trace fossils	Soom biota (Cederberg Formation) is unique post-glacial fossil assemblage showing soft-part preservation
CAPE GRANITE SUITE, YZERFONTEIN SUITE N-€v, N-€m, N-€c, N-€g, N-€i, N-€l, N-€p, N-€s, N-€r, N-€d,		granites and other intrusive, extrusive igneous rocks Ediacaran - Cambrian (c 552-515 Ma)	NO FOSSILS RECORDED	

N-€w, N-€k, €g, Ny etc				
VANRHYNSDORP GROUP	BRANDKOP SUBGROUP €b	shallow marine siliciclastics Early Cambrian	abundant, low diversity trace fossil assemblages dominated by <i>Treptichnus</i> (plus possible arthropod scratches)	key unit for study of Early Cambrian trace fossil evolution
	KNERSVLAKTE SUBGROUP €kn	deep to shallow marine siliciclastics, minor limestones Late Proterozoic (Ediacaran) to Early Cambrian	low diversity shallow to deep marine / offshore trace fossils (eg <i>Oldhamia</i> , <i>Treptichnus</i>), columnar stromatolites in limestones	important trace fossil assemblages spanning Precambrian / Cambrian boundary
	KWANOUS SUBGROUP Nkw	shallow marine limestones, mudrocks Late Proterozoic (Ediacaran)	simple trace fossils associated with microbial mats, possible shelly fossils (cf <i>Cloudina</i>), oncolites possibility of Ediacaran stromatolites, shelly fossils, organic-walled microfossils etc	So far fossils only recorded from Northern Cape outcrops
	Flaminkberg Formation Nfl	coarse braided fluvial siliciclastics Late Proterozoic (Ediacaran)	no fossils recorded, with possible exception of rare trace fossils	
KLIPHEUWEL GROUP €k, Nf		fluvial conglomerates, coastal braided river to shallow marine sandstones, mudrocks (red beds) Cambrian	rare arthropod trace fossils	Trace fossils only recorded from Elands Bay area so far Klipheuwel Group now includes Franschhoek Formation (Nf)
Schoemanspoort Formation (not mapped as separate unit)		fluvial conglomerates and sandstones ?Cambrian / Early Ordovician	no fossils recorded	fossils unlikely (continental sediments)
KANSA GROUP		fluvial and shallow marine siliciclastics Mid to Late Cambrian	no fossils recorded possibility of trace fossils	

Nk			
CANGO CAVES GROUP Nk	mixed siliciclastic and carbonate, shallow to deep marine sediments Late Ediacaran	organic walled microfossils (acritarchs) stromatolites potential for Ediacaran trace fossils, shelly fossils <i>etc</i>	stromatolites in limestones of Matjies River Formation
KAAIMANS GROUP Nka	highly deformed, low grade metasediments (siliciclastics, limestones) Late Proterozoic / Namibian (age uncertain)	no fossils recorded potential for organic-walled microfossils	fossils, apart from microfossils, unlikely due to high levels of deformation
MALMESBURY GROUP Np, Nty, Npo, ?Nbr, ?Nno	moderately deformed metasediments (coastal marine to deep sea siliciclastics, carbonates), minor volcanics Late Proterozoic (late Ediacaran) 550-575 Ma	no fossils yet recorded, <i>but</i> there is potential for organic-walled microfossils, trace fossils, stromatolites, even vendobiontans, shelly fossils like <i>Cloudina</i>	micropalaeontological analysis in progress correlated with lower Vanhynsdorp Group
SWARTLAND GROUP Nbe, Nkl, Nb, Nmo	highly deformed metasediments (siliciclastics, carbonates, cherts), volcanics Late Proterozoic (early Ediacaran) >580-570 Ma	potential for organic-walled microfossils	micropalaeontological analysis in progress correlated with Gifberg Group
GARIEP SUPERGROUP GIFBERG GROUP (Vredendal Inlier) Ng	metasediments (marine siliciclastics, carbonates, glacial tillites) Late Proterozoic (Cryogenian - Ediacaran) <770 Ma - >550 Ma	deformed stromatolites in carbonates (Bloupoort Formation) possible organic-walled microfossils (acritarchs) + agglutinated foraminiferans in siliciclastics	palaeontology poorly known
NAMAQUA-NATAL	igneous intrusions (<i>eg</i> granites) and	NO FOSSILS RECORDED	wide range of basement rocks

<p>METAMORPHIC PROVINCE</p> <p><i>Msc, Mkg, Mbt, Mnp, Mbn, Mkc, Mki, Mkf, Mdt etc</i></p>	<p>high grade metamorphic rocks (<i>eg</i> gneisses) formed or metamorphosed around 1.2-1.0 Ga</p> <p>Mid Proterozoic (Mokolian)</p>		<p>in Namaqualand (<i>eg</i> Little Namaqualand Suite, Spektakel Suite, Kamieskroon Gneiss). Some intrusions as young as 910 Ma (<i>eg</i> Biesiefontein Granite)</p>
--	--	--	---

KEY:

Ma = millions of years old Ga = billions of years old

metasediments = metamorphosed sediments (*eg* quartzite = metamorphosed sandstone).

high grade metasediments = sedimentary rocks that have been strongly metamorphosed, and therefore not fossiliferous (*eg* schist, gneiss), as opposed to **low grade metasediments** that have only been slightly metamorphosed, and may therefore still contain fossils (*eg* quartzites, slates).

siliciclastics = sediments mainly composed of silicate minerals (*eg* quartz, feldspar, clays), as opposed to **carbonates** = sediments composed of carbonate minerals (*eg* limestone, dolomite, calcrete).

fluvial sediments = deposited by rivers (alluvium) **lacustrine sediments** = deposited in lakes **aeolian sediments** = deposited by wind

tillites = glacial sediments **coquinites** = shell beds

pedocretes = secondarily cemented soils (*eg* lime-cemented calcretes, silica-cemented silcretes)

BIF = banded ironstone formations **laterite** = red, iron-rich soils formed from highly weathered bedrock

PALAEONTOLOGICAL SIGNIFICANCE OF ROCK UNITS

COLOUR OF ROCK UNIT	PALAEONTOLOGICAL SIGNIFICANCE / VULNERABILITY	RECOMMENDED ACTION
RED	very high	field scoping study recommended before excavation takes place
PURPLE	high	desk top study + scoping study may be necessary
GREEN	moderate	desk top study
BLUE	low	no action required (any fossil finds to be reported by developer)
BLACK	insignificant or zero	no action required

NB.1. These significance / vulnerability ratings are *provisional*

NB.2. Some rock units are largely unfossiliferous, but have thin subunits of high palaeontological significance (*eg* Table Mountain Group).

PLAN OF THE FOURTEEN 1: 250 000 SCALE
GEOLOGICAL SHEETS
COVERING THE WESTERN CAPE PROVINCE

