

APPENDIX 1: PALAEOONTOLOGY OF THE WHITEHILL FORMATION, LOERIESFONTEIN AREA

(Modified from an unpublished technical report by J.E. Almond (2008) for the Council for Geoscience, Pretoria, and to be incorporated into the geological sheet explanation for the 1: 250 000 geological map sheet 3018 Loeriesfontein. *NB* Full references will appear in this publication, and are not given here)

Excellent exposures of carbon-rich mudrocks of the Whitehill Formation in the immediate vicinity of Loeriesfontein (*eg* along the tar road to Nieuwoudtville) as well as at Ezelfontein to the northwest of town have yielded some of the most important assemblages of animal fossils known from the Ecca Group of the main Karoo Basin. These include mesosaurid reptiles, palaeoniscoid fish, pygocephalomorphic crustaceans, as well as rarer material of fossil wood, insects, trace fossils and palynomorphs (*eg* Jubb & Gardiner 1975, Oelofsen 1981, 1987, Almond 1996, Visser 1992, 1994, Evans & Bender 1994, Evans 2005). The vertical zonation of fish, crustacean and mesosaurid fossils within the Whitehill succession at Loeriesfontein has been outlined by Oelofsen (1981, 1987), Visser (1992, 1994) and Evans (2005). The preservation and stability of fossil material from this area have often been enhanced by thermal metamorphism associated with nearby dolerite intrusions of Jurassic age.

The prolific but low diversity Whitehill fossil biota strongly suggests that non-marine, brackish, freshwater or occasionally even hypersaline salinities prevailed in the basin at the time. This is supported by the local abundance in the middle and upper parts of the succession of pygocephalomorph crustaceans, a group that is typically (though not exclusively) associated with non-marine mudrocks (Gray 1988). Stenohaline marine invertebrates are entirely absent in the Whitehill Formation; purported articulate brachiopods and edrioasteroid echinoderms recorded by Oelofsen (1981) are dubiofossils at best. Stable isotope analyses of Whitehill and coeval carbonaceous, pyritic mudrocks from the Ecca Sea region by Faure and Cole (1999) favour a brackish to freshwater environment (Contrast the fully marine salinities inferred by Stollhofen *et al.* 2006 on the basis of various geochemical proxies in a recent palaeontology-free analysis). The Ecca Basin was therefore already largely isolated from the world ocean (Panthalassa) by the emerging Gondwanide orogen by Mid Permian times. High levels of amorphous organic carbon in the black shales are attributed to extensive blooms of planktic algae - possibly the green alga *Botryococcus*, which has been recorded from the Ecca Basin - that peaked in late Whitehill times (Faure & Cole 1999). The high input of finely particulate carbon into the bottom sediments, combined with poor mixing of the shallow, stratified water column, contributed to prevailing anoxia near and beneath the seabed. Stratification of the extensive Ecca Sea may have been promoted by prevailing warm, humid climates. These are suggested by high chemical weathering rates (Scheffler *et al.* 2006, but contrast Visser & Young 1990 who infer warm climates in Prince Albert times followed by cooler conditions during Whitehill deposition), prolific plant growth (Vryheid Formation coal measures along the northeastern basin margins), and evaporitic conditions (*eg* gypsum precipitation) along the northwestern basin margins during later Whitehill times.

Well-preserved specimens of mesosaurid reptiles and other body fossils have been collected from the upper portion of the Whitehill Formation at several localities in the Loeriesfontein region, such as Ezelfontein, Breeknie, Kafferdam, Klein Rooiberg, Langberg, Blouputs, Witputs, and Leeubergrivier (McLachlan & Anderson 1973, Oelofsen 1981, 1987, Visser 1992, 1994). The small (40-50 cm long) parareptiles of the Family Mesosauridae were endemic to the Early Permian Ecca seaway ("Mesosaurus Sea") of southwestern Gondwana. They are the oldest known (albeit highly specialised) anapsid reptiles as well as the oldest tetrapods recorded from Gondwana. Well-articulated mesosaurid corpses are common, although partially disarticulated remains and isolated bones also occur. The original teeth and bony material have normally been dissolved away during diagenesis to form natural moulds that are frequently

lined, and even partially cast, by secondary minerals such as gypsum and limonite. The high degree of articulation of many mesosaurid and palaeoniscoid specimens in the Whitehill is attributed to the absence of bottom currents, prevailing anoxia and perhaps also high salinity on and above the seabed, excluding most scavengers and bioturbators.

Specimens of the genus *Mesosaurus* are restricted to offshore black shale facies in South America (Parana Basin) as well as Southern Africa (Karoo Basin and Namibia). This was a highly specialised microvorous predator, as suggested by its long, narrow snout bristling with numerous needle-like teeth, long neck, paddle-like limbs, strong propulsive tail and highly unusual pachyostosed (highly thickened) rib cage (Oelofsen & Araujo 1987). This last adaptation may have operated like a diver's belt, allowing the animal to swim and feed well below the surface - perhaps occasionally even on the shallow sea bed - with less effort. Mesosaurids probably fed on individual small nektonic prey items, perhaps soft-bodied plankton, fish eggs and invertebrate / crustacean larvae, rather than straining out krill-like crustaceans with their comb-like teeth as previously hypothesised (Modesto 2000).

Palaeoniscoids are primitive actinopterygian (ray-finned) bony fish with an elongate body, well-developed dermal armour of head plates, a long gape, a single dorsal fin, and a body armour of robust, articulated scales covering the trunk. The systematics and taphonomy of Whitehill palaeoniscoid fish are reviewed by Evans and Bender (1994) and Evans (2005). A high proportion of key specimens were collected from a 40cm thick, prominent-weathering zone towards the top of the Whitehill Formation at various localities in the vicinity of Loeriesfontein (Almond 1996, Evans 2005). Here coarser, silty to fine sandy facies predominate over the normal laminated mudrocks. Most fish are preserved as detailed external moulds of compressions (some composite) in lateral view, although dorso-lateral and oblique, twisted compressions are also seen. Levels of articulation are high to very high [FIG A]. The density of fish fossils at some horizons, such as the Loeriesfontein fish beds, suggests that sporadic mass mortality events occurred, probably due to sudden turnover of a shallow, thermally stratified water column. Some fish specimens show possible signs of tetany (piscine rigor mortis), which may have been induced by anoxia, or sudden fluctuations in water temperature, salinity or pH. Evans (2005) concludes that there are at least five, and possibly as many as eleven, palaeoniscoid species represented in the Whitehill ichthyofauna. These probably included bottom feeding, surface feeding and midwater predators feeding on small prey such as crustaceans, planktic larvae and smaller fish as well as organic detritus. In addition to the widely reported *Ecca* genera *Palaeoniscum* (the commonest form), *Watsonichthys* and *Elonichthys*, Whitehill palaeoniscoids include a new deep-bodied fish of the platysomid group as well as a long-bodied form of the genus *Cycloptychius*, both based on material from Loeriesfontein. Chondrichthyans (cartilaginous fish) and sarcopterygians (lobe-finned bony fish) recorded in coeval beds in Brasil and Namibia are so far unrecorded from the Whitehill Formation. Spiral coprolites suggest that primitive jawed fish of some sort - probably sharks - were indeed present (Evans 2005). Similar coprolites may, however, also be attributed to giant eurypterids (water scorpions) whose trackways and fragmentary skeletal remains are recorded from the early *Ecca* Seaway in South Africa and South America (Almond 2002).

Small (5cm or less long) eocarid crustaceans of the Order Pygocephalomorpha are preserved in their millions as paper-thin compressions within a laterally extensive acme zone towards the top of the Whitehill Formation [FIG B]. The acme zone lies 12-18m below the top of the Whitehill Formation in the Loeriesfontein area according to the fossil range charts of Visser (1992, 1994) but within 3m of the top according to Oelofsen (1987). In the Loeriesfontein sheet area dense assemblages of pygocephalomorphs have been collected from several sites in the vicinity of Loeriesfontein town as well as on the farms Blouputs 1133, Quagga's Klok 321, Naauw Brak 342 and Breek Knie 286 (Kensley 1975, Almond 1996, Visser 1992, 1994, Oelofsen 1981, 1987). Most Whitehill fossil crustaceans are preserved in dorso-ventral view,

though lateral compressions also found. Many specimens are intact, while some are partially decomposed and disarticulated and may represent exuviae (moulted exoskeletons) rather than corpses. Juvenile individuals have not been recognised. Until recently, the Whitehill crustaceans have been referred to a single species, *Notocaris tapscotti*, (previously also referred to the Genus *Pygaspis*; Kensley 1975). Studies of extensive collections from Loeriesfontein and elsewhere, in conjunction with material from the Irati Formation of Brazil, suggest that several genera, and perhaps as many as five different species, are probably present in the Whitehill Formation, including elongate syncarids without a carapace, (Almond 1996, Pinto and Adami-Rodrigues 1996, Adami-Rodrigues in Evans 2005). Three-dimensionally preserved crustaceans preserved within dolomitic nodules from the Whitehill Formation near Prince Albert have been tentatively compared with the Brazilian genera *Paulocaris* and *Liocaris* but have not been recorded from similar nodules in the Loeriesfontein area (Oelofsen 1981, Almond 1996).

Permian pygocephalomorph crustaceans are generally found in non-marine, brackish to freshwater settings, often in association with black shales (Gray 1988). The crab-like folding of the abdomen beneath the carapace suggests a benthic life style in the case of *Notocaris*. They may have been benthic detritus or algal feeders and even low-level carnivores (Gray 1988). The close association of crustacean carapaces with mesosaurid remains in the Irati also suggests a possible scavenging mode of life (F. Sedor in Evans 2005). In turn they were probably an important, but not exclusive, food source for bottom feeding palaeoniscoid fish and even mesosaurids as well. Populations of notocarids thrived in the Ecca Sea during relatively brief intervals when the bottom waters were moderately well oxygenated, but not so well as to allow complete microbial decomposition of the crustacean remains. Very rare insect remains - mainly isolated wings - have been recorded from the Whitehill formation (Geertsema *et al.* 2002). These include undescribed material from the Loeriesfontein area (*eg* a wing from Kaffersdam, Oelofsen 1981). In some cases, isolated, highly ornamented dermal plates of palaeoniscoid fish may have been mistaken for sclerotised insect wings.

Although extensive coal swamp forests flourished along the margins of the Mid Permian Ecca Sea (*cf* Coal Measures of the Vryheid Formation), plant macrofossils are generally rare in offshore mudrock facies of the Whitehill Formation (Anderson & McLachlan 1976). They include petrified tree trunks, glossopterid leaves (*eg* examples collected on the border of Blouputs 1133 and Brek Knie 286 in the Loeriesfontein sheet area) and needle-leaved lycopods (club mosses).

Trace fossils are typically absent from the laminated black shale facies of the Whitehill Formation, probably due to the prevailing anoxic and / or hypersaline bottom waters that excluded almost all larger benthos. Low diversity ichnoassemblages do occur, however, in association with silty horizons towards the middle of the formation at Loeriesfontein and elsewhere within the Trace Fossil Zone of Oelofsen (1981, 1987, Visser 1992, 1994). Whitehill traces comprise *Umfolozia*-like and other arthropod tracks such as *Kouphichnium* (the last attributed to king crabs), various horizontal burrows including so-called *Scolicia*, "fucoid strap" burrows that were originally misinterpreted as kelp-like seaweeds or fleshy stems, and branching burrow networks reminiscent of *Thalassinoides* crustacean burrows (Anderson & McLachlan 1976, Anderson 1975, Oelofsen 1981, Visser 1992, 1994, Almond 1996). A peculiar staggered, three-legged trackway from Kafferdam in the Loeriesfontein sheet area was illustrated, but not named, by Oelofsen (1981). Several other purported Whitehill traces described by the same author are probably dubiofossils, including his ichnogenus *Rosaichnus* based on material from Kafferdam. Hälbich (1962) recorded abundant "fossil leaf impressions" in association with palaeoniscoid fish in the Whitehill Formation of the Langberg near Loeriesfontein; these are almost certainly horizontal burrows of some sort (*cf* Anderson & McLachlan 1976).

A radiometric date for tuffs in the Collingham Formation of 270 ± 1 Ma (Kungurian / Roadian Stages *ie* on the boundary of the Early and Middle Permian) indicates an Early Permian, Kungurian or at most late Artinskian, age for the Whitehill Formation which lies directly below the Collingham in the SW Cape (Stollhofen *et al.* 2000, Turner 1999). A late Artinskian age (278 Ma) for tuffs in the Irati Formation of Brazil, a correlative of the Whitehill Formation, has recently been published (Santos *et al.* 2006, Césari 2007 and refs therein). This supports the Artinskian age previously inferred for the Whitehill on the basis of palynology (Anderson 1981).



A. Well-articulated palaeoniscoid fish (*Palaeoniscum capensis*) from the Whitehill Formation (Iziko: South African Museum, Cape Town).



B. Pygocephalomorph crustacean (*Notocaris*) from the upper Whitehill Formation.