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

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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.

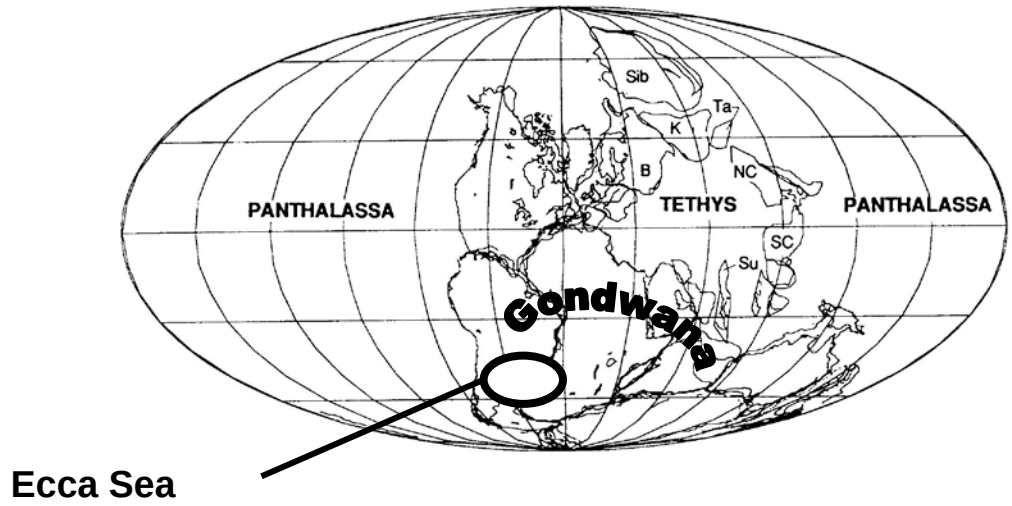

Fig. 1. Palaeogeographic position of the Early to Mid Permian Ecca Sea on Gondwana

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.

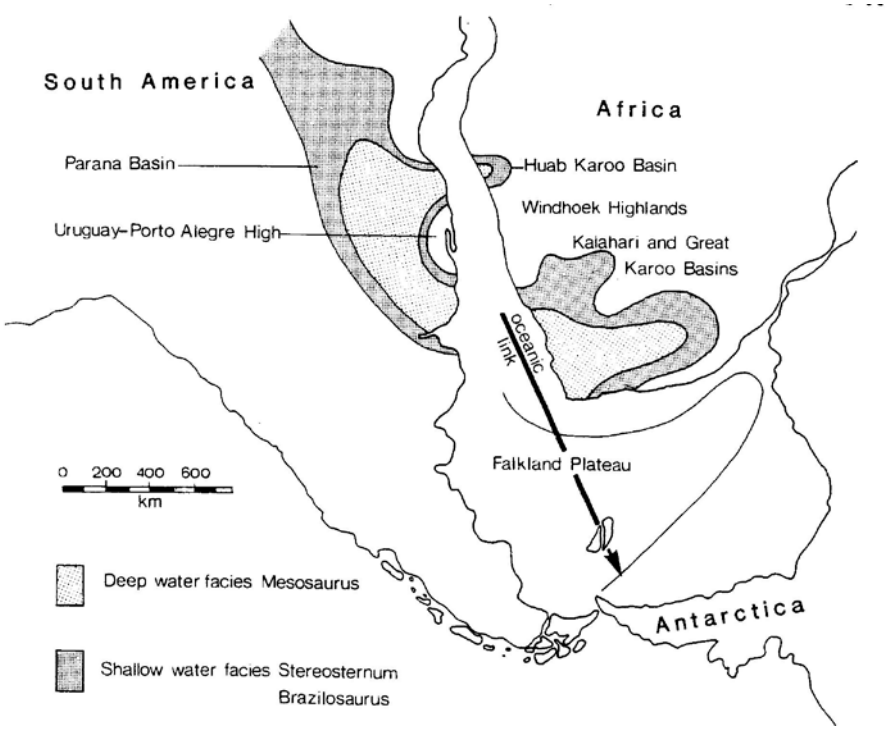

Fig. 2. Geographical extent of the Mesosaurus of Ecca Sea in SW Gondwana

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