6.0 SUMMARY

The primary objective of this thesis has been to investigate the concept of Earth expansion as an explanation for observed global geological and geophysical data. To achieve this a series of 24 spherical models of an expanding Earth have been created to display and present this global data in an expanding Earth framework. The objectives of the Archaean to Recent expanding Earth models have been to display oceanic and continental geology; to investigate the mathematical constraints of a potential Archaean to Recent Earth expansion; to speculate on expansion of the Earth to the future; to display global geological and geophysical data sets; to apply this information to investigate the geological history of Australia; and to speculate on a proposed causal model for Archaean to future Earth expansion.

A set of twenty four spherical models have been constructed, twenty three covering the Archaean to Recent and one projected to five million years into the future. The primary base map used for construction of each model is the *Geological Map of the World* (CGMW & UNESCO, 1990) (Figure 2.1), which provides a comprehensive global coverage of both continental and oceanic time-based geology. The construction of these models relies on the fundamental premise that crustal lithosphere is cumulative with time, and historical markers preserved in the oceanic and continental geology represent a means to accurately constrain both palaeoradius and plate reconstruction from the Archaean to Recent.

Post-Triassic oceanic magnetic mapping demonstrates that all oceans are increasing their surface areas away from the mid-ocean-ridges, including the Pacific Ocean, which has traditionally been considered a sink for disposal of excess lithosphere generated within each of the remaining oceans. Conventional plate reconstructions on a static radius Earth (eg. Scotese *et al*., 1988; Müller *et al*., 1997) consistently show an increasing misfit, moving backwards in time, along each of the mid-ocean-ridge plate margins with a requirement for the introduction of presumed, pre-existing lithosphere to maintain a constant surface area.

Post-Triassic models of an expanding Earth have been reconstructed by successive removal of older geological Periods paralleling the active mid-oceanic spreading ridges and restoring plates to a pre-spreading, or pre-extension configuration along each plate or continental margin respectively, at a reduced Earth radius. During the Triassic, continents envelope the Earth as a complete continental shell and marginal and epi-continental sedimentary basins merge to form a global network surrounding continental cratons and orogenic zones. Reconstructing post-Triassic oceanic lithosphere on expanding Earth models results in a plate fit-together along each mid-ocean-ridge plate margin at better than 99% fit. This unique fit-together empirically demonstrates that post-Triassic Earth expansion is a viable process and justifies extending modelling to the Archaean.

Quantification of an Earth expansion process back to the Archaean requires an extension of the fundamental cumulative lithospheric premise to include continental crust. Continental crust is reconstructed on Pre-Jurassic models using the primary crustal elements cratons, orogens and basins, with expansion primarily manifested as crustal extension within an established network of epi-continental rifts, orogens and sedimentary basins. Moving backwards in time, extension is progressively restored to a pre-extension, pre-orogenic or pre-rift configuration by removing young sedimentary rocks and continental magmatism. During this process the integrity of orogens is retained until restoration to a pre-orogenic configuration is required and the integrity of cratons is retained until all pre-orogenic and non-orogenic basin sediments and continental magmatism are removed. By removing all basin and pre-orogenic sediments a primordial proto-Earth at a palaeoradius of approximately 1700 kilometres is achieved during the Mesoproterozoic, comprising assembled cratons and Proterozoic basement rocks.

Pre-Jurassic expanding Earth models demonstrate that each of the continental tectonic regimes comprising cratons, orogens and basins has maintained spatial integrity throughout the Precambrian and Palaeozoic, prior to Late Palaeozoic continental rupture, break-up and dispersal of continents to the Recent. From an Archaean and Early Proterozoic crustal assemblage of cratons and orogenic basement rocks, a network of Proterozoic intracratonic sedimentary basins coinciding with orogenic basement rocks is established (Figure 5.1). This network represents zones of primary crustal weakness and forms the loci for ongoing continental crustal extension, basin sedimentation and intracratonic mobility during the Proterozoic and Palaeozoic, and represents the loci for continental break-up and opening of the modern oceans during the post-Permian.

Mathematical modelling of oceanic and continental surface area data demonstrates that the Earth is undergoing an exponential increase in palaeoradius, commencing from a primordial Earth of approximately 1700 kilometres radius during the Early Proterozoic. The current rate of increase in Earth radius is calculated to be 22 mm/year. Earth expansion during the Archaean to Late Mesoproterozoic is shown to increase by approximately 60 kilometres during 3 billion years of Earth history, prior to a steady to rapidly accelerating increase in Earth radius during the Neoproterozoic to Recent. Extrapolating Earth expansion to the future demonstrates that expansion to 5 million years in the future is consistent with a continued spreading and elongation of all present-day mid-ocean-ridge axes.

In contrast to conventional geophysical constrained plate tectonic reconstructions Precambrian and Palaeozoic expanding Earth reconstructions are geologically constrained by the spatial configuration of continental tectonic regimes. Similarly, during the Mesozoic and Cenozoic all continents are latitudinally and longitudinally constrained by oceanic geology, which can be further extrapolated to the future. To quantify an Earth expansion process, comprehensive studies in space geodetics, palaeomagnetics, palaeogeography, palaeobiogeography, palaeoclimate and metallogeny have been used to investigate the spatial and temporal distribution of global geological and geophysical data within a conceptual expanding Earth tectonic framework.

Modelling of palaeomagnetic and space geodetic data shows that, by removing the imposed constant surface area and constant radius premises from geophysical observations the data is consistent with Earth expansion. In particular the published palaeomagnetic data of McElhinny & Lock (1996), when used to plot palaeopoles on expanding Earth models, results in a cluster of diametrically opposed north and south geocentric magnetic palaeopoles for each expanding Earth model (Figures 3.13 and 3.14). These show that the north palaeopole was located in eastern Mongolia-China during the Precambrian and Palaeozoic and, as the continents slowly migrated south during expansion there was an apparent northward polar wander through Siberia to its present location within the Arctic Ocean. The Precambrian and Palaeozoic south palaeopole was located in west central Africa and, as the continents slowly migrated north there was an apparent southward polar wander along the South American and west African coastlines to its present location in Antarctica.

Geographical and biogeographical data sets, when applied to expanding Earth models quantify the location of palaeopoles and palaeoequators determined from unconstrained palaeomagnetic data. The distribution of latitude dependent lithofacies including glacials, carbonates and coal, and faunal and floral species is shown to coincide precisely with established palaeopoles and palaeoequators for all expanding Earth models. For climatic and biotic indicators a distinct latitudinal zonation paralleling the established palaeoequator is evident and a distinct northward shift in climatic zonation suggests that an inclined Earth rotational axis, inclined to the pole of the ecliptic, was well established during the Palaeozoic, persisting to the Recent.

Coastal geography on expanding Earth models shows that large Panthallassa, Tethys and Iapetus Oceans are not required during reconstruction. These oceans are replaced by epi-continental Panthallassa, Iapetus and Tethys Seas, which represent precursors to the modern Pacific and Atlantic Oceans and present Eurasian continent. Emergent land surfaces during the Precambrian and Phanerozoic equate to the conventional Rodinian, Gondwanan and Pangaean supercontinents and smaller sub-continents, and demonstrate a spatial intracratonic and intracontinental integrity throughout Earth history. On each model proto-continental development is progressive, with no requirement for random dispersion-amalgamation cycles. Supercontinent configuration is then defined by a progressive extension of epi-continental sedimentary basins, pulsed orogenesis, eustatic and transgression-regression of epi-continental seas, and opening of modern oceans during the Mesozoic to Recent.

Eustatic and transgressive-regressive marine sea-level cycles on an expanding Earth are shown to occur in response to climatic change, to a shift in the distribution of epi-continental seas, orogenesis, mountain building, erosion, opening of post-Permian modern oceans and generation of new juvenile water at mid-ocean-ridges. The variance of these changes to the palaeocoastal outlines results in a change in exposed continental land, coastal transgressive and regressive events, distribution of latitude-dependant sedimentary facies, latitudinal and provincial distribution of biotic taxa and tectonostratigraphic histories.

Orogenesis on an expanding Earth is represented by zones of intracratonic to intracontinental interaction, resulting from gravity induced collapse and partial rotation of cratons and proto-continents as they adjust for changing surface curvature. Tangentially directed crustal motion during this collapse and re-equilibration is manifested as intracratonic to intracontinental rotation, localised within epi-continental sedimentary basins and accompanied by regional synkinematic metamorphism and magmatism. This periodic rotational motion gives rise to long linear and interconnected orogenic belts surrounding each of the primary cratons or proto-continents, with polyphase motion resulting in an extension-orogenesis-extension cyclicity.

A distinction is made between orogeny, which deals with formation of fold belts, and mountain building, which results in vertical uplift to form plateaus. Change in surface curvature during Earth expansion gives a prime mechanism for mountain building where continental interiors initially remain elevated, or arched relative to the intracratonic basins or continental margins. Periodic gravitational collapse of the continental interiors results in isostatic uplift and associated block faulting of the continental margins, forming mountain escarpments. This process becomes cyclical during ongoing expansion, resulting in multiple and overlapping phases of mountain building, planation, sedimentation, uplift and erosion.

The distribution of selected faunal and floral taxa on palaeogeographic expanding Earth models demonstrates the distribution in relation to established palaeogeography, palaeopoles and palaeoequators. The palaeobiogeographic faunal and floral examples used illustrate the ease and simplification of migration and biogeographical development on an expanding Earth. Cosmopolitan and provincial distributions and inter-relationships are maintained, without the need for conventional continental assemblage-dispersal requirements. During continental break-up and opening of the modern oceans traditional migration routes are then disrupted, enabling taxa endemic to the various regions to interact and extend their boundaries with time. The timing of faunal and floral development is then reflected in eustatic and transgressive-regressive sea-level cycles, facilitating evolution, migration or extinction by extending or destroying habitats and migration routes and modifying climate.

Metallogeny on an expanding Earth is considered in the context of metallogenic epochs and metallogenic provinciality. The distribution of ore deposits and the nature and styles of mineralization in time and space suggests that there has been an evolutionary trend in the concentration of metals, as well as diversity in morphological types of mineral occurrences. Metallogenic modelling of Precambrian and Phanerozoic metal deposits shows a broad global Precambrian metallogenic provinciality coinciding with cratons and intracratonic settings, to regional provinces clustering as specific metal associations. The Phanerozoic metallogenic distribution highlights the abundance of porphyry and granite associated metals concentrated within Phanerozoic orogenic belts. On an expanding Earth these Phanerozoic orogenic belts crosscut and displace pre-existing Palaeozoic and Precambrian metallogenic provinces and a common mantle source for various metal associations is evident.

The conceptual expanding Earth framework established from modelling is used to investigate the spatial and temporal tectonostratigraphic history of Australia. Australia is located adjacent to Archaean cratons and Proterozoic and Phanerozoic terranes from China, North America, South America and East Antarctica. Much of Australia has been largely intact since about 2.5 Ga and most subsequent orogenic activity has been ensialic (Rutland, 1973; Etheridge *et al*., 1987; Wyborn, 1988). A distinct tectonic directional grain recognised in the Yilgarn Craton (Rutland *et al*., 1990) parallels the directional grain in the Canadian Churchill and Superior Provinces. This is consistent with oblique east-west (Precambrian orientation) crustal extension between the Australian Archaean Superprovinces and the Canadian Archaean Slave, Churchill and Superior Provinces, followed by oblique ensialic translational motion during a global-wide Palaeoproterozoic Barramundi and later orogenic events.

North and east Australian Middle Proterozoic orogenic events are aligned with the Grenville Orogenic event of eastern North America and the Tasman event of eastern Australia. On an expanding Earth, the Tasman Superprovince is intracratonic to the Central Australian Proterozoic terranes, the Amazon Craton of South America and remnant terranes in Central America, and extends to include Palaeozoic basins in southeast North America, West Antarctica and southern South America. Development of the superprovince represents an extended period of crustal divergence and intracratonic basin sedimentation between Australia and South America during Earth expansion.

A causal model for Earth expansion is based on a study of the kinematics of the Earth (Section 2.3 and Appendix A1), which suggests that expansion is caused by an exponential increase in mass with time. Carey (1983a, 1996) concludes that matter is being created deep within Earth's core, in sympathy with creation and expansion of matter within the Universe. The proposed causal model for Earth expansion involves an increase in mass by condensation, or segregation of new matter from the Earth's core. This new matter accumulates at the core-mantle interface and the increase in volume results in a swelling of the mantle. Mantle swell is then manifested in the outer crust as continental crustal extension and extension along the mid-ocean-rift zones. Matter generation within the Earth's core is seen as an endothermic reaction, which will ultimately result in a decay of the matter formation process within the core and cessation of expansion with time.

On an expanding Earth causal model the pre-Archaean Earth-Moon was an incandescent mass ejected from the surface of a primitive young Sun. Gravitational instability resulted in separation of the Earth and Moon, forming a binary planet with high surface temperatures and elevated geothermal gradients. By the Early Archaean surface temperatures were sufficiently low to allow solidification of a thin sialic crust on Earth. During the Early Archaean the Earth mantle retains a high global geothermal gradient and hot, mantle-derived surface water pools within low-lying surface depressions. The survival of a 30 to 40 kilometre thick Archaean crust on the present Earth implies the stabilisation of a subcrustal root-zone not less than 200 kilometres thick during the Early Archaean (Wells, 1981).

By the Late Archaean cratonisation of the Earth's crust was complete and basin extension during expansion results in large, stable platforms with a low elevation contrast between continents and seas. The Proterozoic represents an epoch of comparative crustal stability and increasing mobility, with volcanic and sedimentary sequences deposited within well defined, elongate basins representing a global network of intracratonic basin extension. Polyphase extension-mobility-extension is a prime feature of the Precambrian Earth causal model, extending through to the Palaeozoic, prior to continental crustal rupture during the Early Permian and continental break-up and dispersal during the Mesozoic and Cenozoic to the Recent.