1. INTRODUCTION

Global tectonics is a concept that embraces and integrates all facets of the Earth sciences and includes theories as diverse as plate tectonics and Earth expansion. The rapid increase in global tectonic research during the past three decades, coupled with advances in computer technology, has resulted in the accumulation of a vast array of global geological and geophysical data. This data, while routinely used in conventional plate tectonic studies, has previously not been applied to an expanding Earth model.

In this thesis it is intended to use global geological and geophysical data, including examples from geology, space geodetics, palaeomagnetics, palaeogeography, palaeobiogeography, palaeoclimate and metallogeny to investigate a potential Archaean to Recent Earth expansion process. The primary geological and geophysical data, including spatial configuration of established crustal plates, is not contested in this thesis, only the global tectonic platform used to quantify the data.

The terms Earth expansion and expanding Earth model used in this thesis refer to crustal extension and lithospheric plate motion on an Earth whose surface area increases with time in sympathy with an increase in Earth radius. This increase in surface area is manifested primarily as extension within the oceanic mid-ocean-rift zones and as crustal extension within continental rift zones and sedimentary basins.

The investigation of Earth expansion dates back to the modelling studies of Hilgenberg (1933) and has since been extensively promoted by Carey (1958, 1976, 1988, 1996) and modelled by Vogel (1983, 1984, 1990). Past rejection of Earth expansion as a viable alternative tectonic concept dates back to the 1960s and 1970s, before the development of modern plate tectonics, and is based primarily on the inability of early researchers to quantify an expansion process and constrain expansion against time. Since the completion of modern global geological and geophysical data sets quantification of an Earth expansion process is now possible.

In contrast, conventional plate tectonic theory has been promoted to explain a diverse range of tectonic phenomena and is now widely accepted in science. The term conventional is used in this thesis to refer specifically to the plate tectonic model, characterised by lithospheric plate motion on an Earth of essentially fixed volume and surface area. In plate tectonic theory, palaeomagnetic determinations of palaeoradius have been used to conclude that Earth's radius has remained approximately constant throughout geological history (eg. McElhinny & Brock, 1975). Based on this conclusion the outer lithospheric crust of the Earth is then portrayed as being segmented into a mosaic of rigid, shifting plates created at oceanic ridges, consumed at oceanic trenches and sliding past one another along transform faults (Chatterjee & Hotton, 1992). Chatterjee & Hotton (1992) consider that this dynamic model links all geologic phenomena, from the age and composition of sea floors to the rise of mountains and the past distribution of flora and fauna.

Intensive geological and geophysical research since the introduction of both Earth expansion and plate tectonic theories has now increased the global database available to thoroughly test all global tectonic theories. In particular, space geodetic, palaeomagnetic, palaeogeographic, palaeobiogeographic and palaeoclimatic studies have advanced to enable quantification of plate reconstruction of continents and their displacement histories throughout geological time. An important geophysical contribution to the quantification of modern global tectonics has been the completion of oceanic magnetic mapping and radiometric and palaeontologic age dating of crust beneath all Earth's major oceans. This oceanic mapping has placed finite time constraints on the plate motion history of all ocean basins back to the Early Jurassic, and is now available to quantify plate reconstruction and rate of crustal generation on both plate tectonic and expanding Earth models.

Previous research into post-Triassic Earth expansion (Maxlow, 1995) utilised the oceanic mapping of CGMW & UNESCO (1990) to constrain plate reconstructions on models of an expanding Earth extending from the Recent to Early Jurassic. By successively removing oceanic geology from along mid-ocean-ridge spreading axes shown in CGMW & UNESCO (1990), and reuniting the primary continental and oceanic plates at reduced Earth radii, Maxlow (1995) demonstrated that all crustal plates reunite with a better than 99% fit-together for each model constructed. It was concluded from this research that, oceanic magnetic mapping provides a definitive means to test and quantify a potential rate of Earth expansion and a means to constrain plate configuration with a precision not previously available to early researchers. The post-Triassic modelling studies by Maxlow (1995) then prompted the need to extend research to the Archaean by incorporating continental geology and applying the concept of Earth expansion to modern geological and geophysical data.

1.1 Research Objectives

The primary objective of this thesis is to investigate the concept of Earth expansion as an explanation for observed Archaean to Recent global geological and geophysical data. To achieve this objective a series of 24 spherical models of an expanding Earth have been constructed using 300 millimetre diameter polystyrene foam spheres. These spheres have then been digitally resized to the same scale to display and present global geological and geophysical data in an expanding Earth conceptual framework.

The constructed spherical models form the basis for secondary objectives, including:

1. The reconstruction of oceanic and continental geology on each expanding Earth model, ranging in age from the Archaean to Recent.
2. An application of mathematical constraints to the models to investigate the rate and variation of a potential Archaean to Recent Earth expansion process.
3. Speculation on a potential future expansion of the Earth by reconstructing oceanic and continental geology at 5 million years into the future.
4. The use of published palaeomagnetic data to locate palaeopoles and establish palaeoequators and palaeogeographical grids on each expanding Earth model.
5. An investigation into the distribution of global geological and geophysical data in relation to reconstructed geology and the established palaeogeographical grids.
6. An investigation into the geological history of Australia in relation to adjoining continents.
7. Speculation on a proposed model for the causal mechanisms of Earth expansion, from the pre-Archaean to the distant future.

It is acknowledged that if the concept of Earth expansion is wrong then the global geological and geophysical data will highlight any inconsistencies on the expanding Earth models. It is also acknowledged that specific studies in each of the geological and geophysical fields to be investigated, when taken out of conventional plate tectonic context, may lead to quite different interpretations to accepted plate tectonic practice. Provision is made to compare and contrast these interpretations and present Earth expansion as a viable alternative tectonic concept.

1.2 Research Methodology

On a celestial scale, the Earth can be considered a sphere and spherical models represent the best means to display geological and geophysical data. Traditional map projections cannot be used to model this data on an expanding Earth because of inherent unrealistic projection distortion and the difficulty in reconstructing accurate global plate configurations in a map format.

This research therefore represents the first time that modelling of the Earth's crust to the Archaean has been attempted and the first time that continental and oceanic geology has been utilised for plate reconstruction. To achieve the objectives of this research, research methodology will involve four interactive phases, with each phase dependant on the completion and quantification of the previous.

The four phases include:

1. **Empirical modelling**: Construction of a series of 24 spherical models of an expanding Earth, ranging from the Archaean to 5 million years into the future, by utilising published maps of Phanerozoic and Precambrian continental and oceanic geology to constrain palaeoradius and plate configuration. These empirical models are used to determine a mathematical expression for a potential rate of Earth expansion to enable palaeoradius to be constrained against time.
2. **Database Modelling**: Application of published global geological and geophysical data to the expanding Earth models to investigate the spatial and temporal distribution of the data within a conceptual expanding Earth tectonic framework. This information is to be used to establish the interdisciplinary relationships and to compare and contrast with conventional plate tectonic distributions.
3. **Detailed Study**: To use this conceptual framework to investigate the spatial and temporal tectonostratigraphic history of Australia, with emphasis on the metallogenic distribution with respect to adjoining intercontinental cratons.
4. **Speculation**: To speculate on a causal mechanism for a potential Earth expansion process from the pre-Archaean to the future, based on the results of the empirical expanding Earth models and the distribution of applied geological and geophysical data.

1.3 Thesis Presentation

Because of the difficulty in displaying the large amount of spherical modelling involved in this research coloured figures are used wherever possible, with video animations replacing selected figures in a CD-ROM disc (Appendix A6; back cover of Volume 2 of 2). The video animations listed in Appendix A6 are accessed via hyperlinks within the CD-ROM as required. It is advisable to read the text in conjunction with these video animations in order to gain a full four-dimensional visual appreciation of the expanding Earth concept.

Videos have been created from a series of 72 GIF images of each expanding Earth model taken at intervals of 5° longitude and centred on the established equator. These images are then assembled into video clips in Adobe Premiere version 5.0 at 640 x 480 pixel frame size, 24 fps frame rate and saved in MPG file format. The range of video clips (Appendix A6) include:

1. Video clips of each individual model at an as-constructed 300mm diameter model size.
2. Video clips of each individual model digitally re-sized to the same scale.
3. Video clips of both as-constructed and re-sized Archaean to Future models assembled into extended video strings.

1.4 Post-Triassic Expanding Earth Research

Research into post-Triassic Earth expansion was presented in Maxlow (1995). This research utilised the oceanic magnetic mapping of CGMW & UNESCO (1990) to recreate models of an expanding Earth previously constructed by Hilgenberg (1933), Barnett (1962) and Vogel (1983). Oceanic magnetic mapping was not available to these early model makers and its completion represents a means to accurately constrain post-Triassic reconstructions and a means to quantify palaeoradius against time.

It was concluded from the oceanic model studies presented in Maxlow (1995) that post-Triassic Earth expansion is a viable tectonic process, which justifies extending research back to the Archaean and speculating on expansion into the future. This thesis uses Maxlow (1995) as a basis to extend and elaborate on the concept of Earth expansion by additional modelling studies and extensive global data investigation. The following is a brief summary of the geological implications addressed in Maxlow (1995).

Since the modelling studies of Hilgenberg (1933), Barnett (1962, 1969) and Vogel (1983, 1984, 1990) it has been demonstrated that if all of the Earth's continents were fitted together they would neatly envelope the Earth with continental crust at approximately 55 to 60 percent of the present Earth size. This led Hilgenberg (1933) to conclude that Earth expansion resulted in the break-up and gradual dispersal of continents as they moved radially outwards during geological time. Vogel (1983) suggested it was also theoretically possible for the continents, without shelves, to fit together at approximately 40 percent of the present Earth radius by considering that continental shelves were formed after the continental crust had fragmented. Vogel (1983) concluded from his modelling studies that the Earth has expanded with time, from an early Pangaean configuration to the Recent, with continental separation caused by a radial expansion of the Earth.

Carey (1958), in researching the concept of continental drift, demonstrated that if all the continents were reassembled into a Pangaean configuration on a model representing the Earth's modern dimensions, the fit was reasonably precise at the centre of the reassembly and along the common margins of north-west Africa and the United States east coast embayment, but became progressively imperfect away from these areas. Carey (1958) concluded from this research that the fit of the Pangaean reassembly could be made much more precise in these areas if the diameter of the Earth was smaller at the time of Pangaea. With the acceptance of plate tectonics, these basic observations and conclusions of Carey (1958) have since been ignored.

To quantify a variation in Earth's palaeoradius and constrain post-Triassic plate configuration with time using oceanic mapping, it was considered necessary to take into account the area and sea-floor pattern of post-Triassic oceanic lithosphere (Maxlow, 1995), portrayed in global geological maps such as Larson *et al.* (1985) and CGMW & UNESCO (1990). By using the method of least squares to calculate gradients of curves of best fit from digitised cumulative oceanic area data, the goodness of fit of the resultant curves was best described by an exponential increase in lithospheric area with time. Palaeoradius was then determined from this cumulative area data and an equation for a post-Triassic increase in palaeoradius of the Earth established.

To present Earth expansion as a viable global tectonic concept and test the derived mathematical expression for expansion a series of eleven spherical models were constructed in Maxlow (1995) utilising the global geologic data of CGMW & UNESCO (1990) (Figure 1.1). These models demonstrate that continents, when reconstructed on an expanding Earth, coincide fully with the sea floor spreading and geological fit-data and accord with the derived mathematical expression for palaeoradius. This coincidence applied not only to the passive margin oceans, where conventional reconstructions agree in principle, but also to the Pacific Ocean where the necessity for subduction of all or part of the oceanic lithosphere generated at spreading ridges was contested. Maxlow (1995) demonstrated that the mechanism of sea-floor spreading defined by oceanic mapping provides a definitive means to accurately quantify post-Triassic Earth expansion.

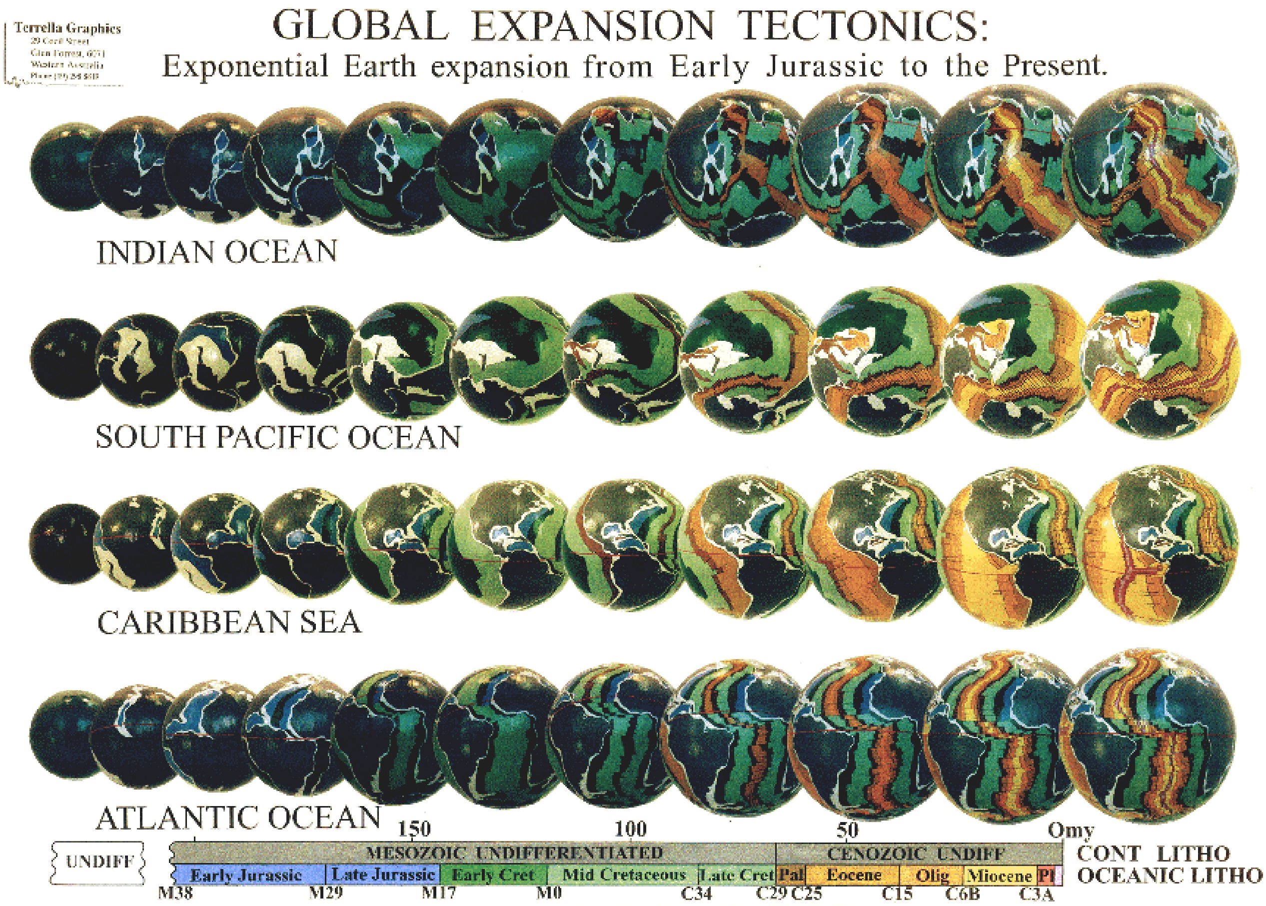

Figure 1.1 Spherical models of post-Triassic Earth expansion (after CGMW & UNESCO, 1990). Models demonstrate that continents reconstructed on an expanding Earth coincide fully with sea-floor spreading and geological data and accord with a derived mathematical expression for an exponential increase in palaeoradius (after Maxlow, 1995).

Models for relief of surface curvature and orogenesis during Earth expansion were considered at length by Rickard (1969), Carey (1975, 1976, 1983b, 1988) and Glikson (1979). Relief of surface curvature was an expression used by Maxlow (1995) defining a process of crustal adjustment by intracratonic motion and gravity induced collapse to relieve vertically induced crustal stresses during an increase in palaeoradius. Orogenesis on an expanding Earth was restricted to zones of intracratonic to intracontinental interaction, magmatism and syn-kinematic metamorphism, resulting from gravity induced collapse, isostatic adjustment and relative motion of proto-continents as they adjusted for changing surface curvature.

Post-Triassic orogenesis on an expanding Earth was considered to be intimately related to a process of asymmetric expansion (Maxlow, 1995). Asymmetric Earth expansion resulted in a northward shift of the continents during continental break-up, with a preferential development of oceanic crust and opening of oceans in the southern hemisphere. This asymmetric expansion initially resulted in establishment of large epi-continental sedimentary basins, prior to continental break-up and dispersal to the Recent. The post-Triassic expanding Earth models (Figure 1.1) empirically demonstrate the onset of Alpine-Himalayan orogenesis as continental crust fragmented, interacted and dispersed during an accelerating post-Triassic increase in surface area.

Rickard (1969) and Carey (1975, 1976, 1983b, 1988) put forward models for orogenesis and geosynclinal development under conditions of surface curvature adjustment and demonstrated that continental collision may not be required to promote orogenesis, as required by plate tectonics. The magnitude of both horizontal shortening and extension of crust, during isostatic adjustment of surface curvature, demonstrated the potential for both tangential and radially directed motion acting within a continental plate during expansion of the Earth. The radial and tangential vector components of this expansion process gave rise to a continuum of orogenic models.

During Earth expansion the whole column of atmosphere, hydrosphere, oceanic lithosphere and underlying mantle was considered to have been added at an accelerating rate through geological time (Maxlow, 1995). Carey (1983b) suggested that this column is accreted primarily at the mid-ocean-spreading ridges and rift zones with the generation of ocean water and atmosphere keeping pace with the growth of oceanic lithosphere.

The nature of mantle fluids and mantle metasomatism indicated (eg. Anderson, 1975; Wyllie, 1979; Jackson & Pollark, 1987; Menzies & Hawkesworth, 1987) that the volatile species in the system C-O-H-S can exist in the Earth's mantle in volatile bearing minerals, dissolved in silicate- or carbonate-rich melts, in a separate supercritical fluid or possibly in a dense silicate-volatile fluid. It was considered by Eggler (1987) that solution of volatiles in crystalline minerals represents a significant repository for volatiles. During Earth expansion, retention of these species within the mantle may be possible by potentially high P-T (pressure, temperature) and low g (surface gravity) conditions (Maxlow, 1995). Devolatilization of the C-O-H-S system to form the hydrosphere and atmosphere then becomes a progressive and possibly accelerating process of devolitilisation of the mantle with time, as a direct consequence of a variation in the prevailing P-T-g conditions.

Palaeomagnetics is traditionally considered the cornerstone of modern plate tectonics and was extensively interrogated in Maxlow (1995). Fundamental premises regarding the constancy of continental surface area, used to determine palaeoradius from palaeomagnetics, originate from the early 1960s prior to development of modern global tectonic concepts and completion of the oceanic crustal database. Mathematical equations developed by palaeomagneticians insist that continental surface areas have remained essentially constant (eg. van Hilten, 1968) and any variation in palaeoradius has been negligible with time (McElhinny & Brock, 1975). Since the establishment of palaeomagnetics, modern global tectonic concepts have demonstrated that the Earth's crust is not a passive adjunct of lithospheric plates but a dynamic, interactive layer of the Earth (Grant, 1992). The application of palaeomagnetics to determine a palaeoradius of the Earth was then considered by Maxlow (1995) to be misleading and in need revision.

The potential causes of Earth expansion were investigated by Maxlow (1995) and extensively reviewed by Egyed (1963), Wesson (1973) and Carey (1983a). Five main themes were considered, including:

1. **A pulsating Earth** where cyclic expansion of the Earth opened the oceans and contractions caused orogenesis (eg. Khain, 1974; Steiner, 1967, 1977; Milanovsky, 1980; Smirnoff, 1992; Wezel, 1992). This proposal failed to satisfy exponentially waxing expansion. Carey (1983a) considered the theme to have

arisen from a misconception that orogenesis implies crustal contraction and saw no compelling evidence for intermittent contractions.

2. **Meteoric and asteroidal accretion** (eg. Shields, 1983a, 1988; Dachille, 1977, 1983; Glikson, 1993). This was rejected by Carey (1983a) as the primary cause of Earth expansion since expansion should then decrease exponentially with time. It also does not explain ocean floor spreading.
3. **A constant Earth mass** with phase changes of an originally super-dense core: (eg. Lindemann, 1927; Egyed, 1956; Holmes, 1965; Kremp, 1983). Carey (1983a) rejected this because he considered the theme to imply too large a surface gravity throughout the Precambrian and Palaeozoic.
4. **A secular reduction of the universal gravitation constant, G** (eg. Ivanenko & Sagitov, 1961; Dicke, 1962; Jordan, 1969; Crossley & Stevens, 1976; Hora, 1983). Such a decline of G was considered to cause expansion through release of elastic compression energy throughout the Earth and phase changes to lower densities in all shells. Carey (1983a) again rejected this proposal as the main cause of expansion for three reasons: a) that surface gravity would have been unacceptably high; b) that the magnitude of expansion would probably be too small and; c) the arguments for a reduction in G were considered not to indicate an exponential rate of increase.
5. **A cosmological cause involving a secular increase in the mass** of the Earth (eg. Hilgenberg, 1933; Kirillov, 1958; Blinov, 1973, 1983; Wesson, 1973; Carey, 1976; Neiman, 1984, 1990; Ivankin, 1990).

Carey (1983a) considered that the first four proposals for cause of Earth expansion are soundly based and may have contributed in part to Earth expansion. Potential limitations on surface gravity in the past (eg. Stewart, 1977, 1978, 1983) suggested to Carey (1983a) that there may be no alternative but to consider an exponential increase of Earth mass with time as the main cause for expansion. Where the excess mass came from was considered at length by Carey (1983a, 1988, 1996) and he suggested that new mass added to the Earth must occur deep within the core. The ultimate cause of Earth expansion must however be sought in conjunction with an explanation for the cosmological expansion of the Universe (Carey, 1996).

It was concluded in Maxlow (1995) that post Triassic Earth expansion is a viable alternative global tectonic process which enables the dynamic principles behind all major geologic phenomena to be resolved and readily explained.