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Preface

Comparative tectonic and dynamic analysis of cratons, orogens, basins, and metallogeny: A special volume to honor the career of Brian F. Windley

1. Preface

Cratons, orogens, and basins of the world each show a distinctive pattern of evolution and metallogeny, and relationships to supercontinent cycles. Some aspects of these histories have remained similar through time, yet others have changed with Earth's changing biota, heat production and flow, and atmospheric composition and temperature. To understand the similarities and differences between these cratons, orogens, and basins through time, we need systematic comparative tectonic analyses between these different elements from similar and widely different ages. One of the pioneers in comparative tectonic analysis is Brian F. Windley, whose research has spanned all of these topics, and more, for more than five decades. This special issue is a tribute to his career.

Brian's career began with graduation from Liverpool in 1960, after which he went to Exeter University for his PhD studies under Ken Coe, working on the Precambrian rocks of SW Greenland, which led to a six year contract working for the Geological Survey of Greenland mapping most of the Precambrian of western Greenland. Brian enjoyed this time, but did not want to be constrained to only mapping the geology of Greenland, so moved on to Leicester University, from where he based the rest of his career. During this career Brian visited many universities around the world (see review of Brian's career in Kusky et al., 2010), and worked on problems in tectonics, mineralogy, geochemistry, geochronology, and metallogeny from every continent (and the moon). Brian has not slowed down in his career and is currently active in many projects in the Central Asian Orogenic Belt, India, Madagascar, China, Scotland, and other places and is currently working on a new edition of his book "The Evolving Continents" with his colleague T. Kusky.

We have collected 29 papers from Brian's peers and colleagues along these themes for this special issue of Tectonophysics and summarize them from "snippits" of the papers here. The papers are organized into five themes, namely Archean Tectonics, Proterozoic Tectonics, Structural and Metamorphic Evolution of Orogens, Tethyan and Paleo-Asian Tectonics and the Central Asian Orogenic Belt, and the Supercontinent Cycle and Earth History. We hope readers enjoy reading these papers as much as the authors have enjoyed working with Brian and doing the science to prepare them.

2. Archean tectonics

Five papers focus on different aspects of Archean tectonics. Peng et al. (2015) present a study of the Qingyuan high-grade granite-greenstone terrane in the North China craton, consisting of circa 2510 Ma ultramafic-mafic-felsic rocks, 2570–2510 Ma quartz diorite, a similar aged TTG suite, and a 2510–2490 Ma quartz monzonite. Using mainly petrologic and geochemical methods, Peng et al. (2015) model the petrogenesis to be related to Archean subduction in a mantle wedge-absent flat-hot-subduction system, with considerable vertical accretion of magmatic rocks. The ultramafic-mafic rocks are interpreted to be derived from the primitive mantle, whereas the meta-dacite-rhyolite originated from eclogite facies overriding crust. The quartz diorite is interpreted by Peng et al. (2015) as a mixture of melts from mantle and the overriding crust, the TTG was derived from the subducting slab under amphibolite to amphibole-bearing eclogite facies conditions, and the quartz monzodiorite was derived from the overriding middle-lower crust. The Qingyuan terrain represents the root of a Neoarchaean arc and its anticlockwise P–T-path records the initiation of the arc at ~2570 Ma to its cession and exhumation/cratonization at ~2480 Ma.

Arai et al. (2015) document intermediate P/T type regional metamorphism of the 3.7–3.8 Ga Isua Supracrustal Belt from southwest Greenland. Using a group of metabasites that range in metamorphic grade from greenschist to amphibolite facies, and they model isochemical phase diagrams with the Perple_X software. The metamorphic pressure and temperature both increase systematically to the south from 3 kbar and 380 °C to 6 kbar and 560 °C. The monotonous metamorphic P–T change suggests that the northeastern part of the ISB preserves regional metamorphism resulting from the subduction of an accretionary complex, although there are also Neoarchean metamorphic overprints. Both the presence of the regional metamorphism and an accretionary complex having originating at a subduction zone suggest that the ISB may be one of the oldest Pacific-type orogenic belts in the world (see also Komiya et al., 2015, for an example of an Eoarchean (>3.95 Ga) Pacific-type orogenic belt). The metamorphic conditions are similar to extant zones of subducting young oceanic crust such as the Philippine Sea Plate in SW Japan. Since this type of metamorphism is characteristic of most Archean terranes, Arai et al. (2015) suggest that subduction of young micro-plates was common in the Archean.

Polat et al. (2015) describe the Eoarchean to Neoarchean tectonic zonation of West Greenland and interpret these as a series of accreted accretionary prisms, island arcs, and fore-arcs. They compare the structures, particularly those of high-grade migmatites with those recently documented by Wang et al. (2014) from the Mesozoic Sulu orogen of China. Polat et al. (2015) document that melting of the metavolcanic rocks during tectonic thickening of arcs during collision is important in the generation of TTG's, and that the style of deformation along with partial melting in the Archean of Greenland is similar to that of the Sulu orogen that formed by subduction processes, suggesting that subduction and collision, and hence plate tectonics, also operated in the early Archean.

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Komiya et al. (2015) describe the geology of the Eoarchean (>3.95 Ga) greenstone belt from the Saglek block in Labrador, which is the oldest recognized greenstone belt/supracrustal assemblage on the planet. Through a series a beautiful and exceedingly detailed field maps and illustrations they show that the Nulliak supracrustal rocks consist of stacks of fault-bounded blocks, locally marked by duplex structures, consisting of the ultramafic rocks, mafic rocks and sedimentary rocks in ascending order, similar to modern ocean plate stratigraphy (OPS) (e.g., Kusky et al., 2013). The presence of duplex structures and OPS indicates that the >3.95 Ga Nulliak supracrustal belts formed in an oceanic accretionary complex in the Eoarchean. The presence of the accretionary complex, ophiolite and granitic continental crust provides the oldest evidence for the plate tectonics on the early earth.

Samuel et al. (2015) examine the Nilgiri Block of southern India, which represents an exhumed lower-crustal section formed during Neoarchean arc magmatic processes. They use phase diagram modeling and U–Pb SHRIMP data to constrain the evolution of charnockites, gneisses, volcanic tuff, metasediments, banded iron formation and mafic-ultramafic bodies in the Nilgiri Block. The rocks follow an anticlockwise P–T–t path with M1 at 850–900 °C at 9 kbar, M2 at 850–900 °C at 14–15 kbar, then followed by amphibolite facies metamorphism. The U–Pb dating shows that arc magmatism occurred at 2539 Ma, and the HT-HP metamorphism at 2458 Ma. Samuel et al. (2015) relate this to late Neoarchean arc magmatism followed by early Paleoproterozoic high temperature, high-pressure granulite facies metamorphism due to crustal thickening during suturing of the Nilgiri Block with the Dharwar Craton.

3. Proterozoic tectonics

Nine papers cover various aspects of Proterozoic lithospheric evolution. Kröner et al. (2015) report the results of a field transect along the northern margin of the Epupa Metamorphic Complex along the Kunene River in Namibia, with detailed U–Pb analysis of rocks from this remote region. Most rocks are late Paleoproterozoic in age (1757–1835, with one older sample at circa 1861 Ma), and together with equivalent rocks from Kaokoland and in the Kamanjab Inlier, form a magmatic province on the SW margin of the Congo Craton possibly related to arc magmatism during the Africa-wide Eburnian event (circa 2000 +/— 200 Ma).

Mandal et al. (2015) report the results of a geological and gravity study across the Rengali Province — Eastern Ghats boundary in eastern India. They document a positive-to-negative Bouguer anomaly across this boundary where Proterozoic granulites of the Eastern Ghats Belt (EGB) form part of a mobile belt to the south of the late Archaean, amphibolite facies Rengali Province. The northern margin of the EGB with the Rengali Province is a sub-vertical Cambro–Ordovician strike-slip shear zone, over which the Talchir Gondwana sedimentary basin was deposited during late Paleozoic extension. 2D and 3D modeling of the gravity data, along with geological studies, show that typical cratonic crust exists beneath both terranes at depths of greater than 7 km. This most likely means that the EGB were thrust over the craton after granulite facies metamorphism, and with erosion, has left the present day EGB granulites resting allochthonously on the low-density crust below.

Zhai et al. (2015) describe Late Paleoproterozoic–Neoproterozoic rifting events in the North China Craton (NCC). These include the Xiong'er aulocogen system in the south central NCC, the Yanshan aulacogen system in the north-central NCC, the Northern marginal rift system in the northwestern NCC and the Eastern marginal rift system in the eastern NCC. Zhai et al. (2015) recognize four stages of magmatic activity in these rifts, including (1) the ~1800–1780 Ma Xiong'er igneous province (XIP), (2) ~1720–1620 Ma anorogenic magmatic association, (3) ~1350–1320 Ma diabase sill swarm, and (4) a ~900 Ma mafic dyke swarm, suggesting that the NCC was located within a larger plate between 1.8 and 0.7 Ga.

Archibald et al. (2015) present detrital zircon data from Proterozoic metasedimentary rocks of central Madagascar to interpret the Neoproterzoic setting of Madagascar and evolution of the East African Orogen. They present data from the Ambatolampy Group and compare these data to similar data from the other sedimentary packages in central Madagascar. New UPb (SHRIMP) zircon data for the Ambatolampy Group yield detrital age maxima of ~3000 Ma, ~2800–2700 Ma, ~2500 Ma, ~2200–2100 Ma and ~1800 Ma. The youngest near-concordant detrital zircon age is 1836 ± 25 Ma. Metamorphic zircons yield ages of 540 Ma, constraining the minimum depositional age. Archibald et al. (2015) use these data to suggest that central Madagascar contained a Mesoproterozoic (to possibly Tonian) siliciclastic sedimentary basin.

Oliveira et al. (2015) also use detrital zircon U–Pb geochronology along with Nd-isotopes to constrain the provenance of sediments in the Neoproterozoic Sergipano Orogen, Brazil (the main orogen between the Sao Francisco Craton and the Bororema Province), and document its evolution from an early passive margin (1000–900 Ma protoliths) to a younger foreland basin, with zircon populations of 570, 600, and 920–980 Ma.

Asanuma et al. (2015) reconstruct the Neoproterozoic Ocean Plate Stratigraphy (OPS) from the Gwna Group, NW Wales, and discuss the implications for a Proterozoic trench-forearc system. The OPS consists of mélange with pillow basalts, cherts, mudstones, and sandstones, with two groups showing different maximum depositional ages of 608–601 Ma, and 564–539 Ma. Asanuma et al. (2015) conclude that the clastic sediments at the top of the OPS were deposited in a trench on the western active margin of Avalonia when it was close to the Amazonian craton, and that the Gwna Group OPS began to be incorporated into an accretionary wedge in an active subduction zone in the latest Proterozoic.

Zhang et al. (2015) present high-resolution aeromagnetic data for the Hengshan–Wutai–Fuping region in the Central Orogenic Belt (a.k.a. TNCO) of the North China Craton, and correlate the aeromagnetic signatures with existing geological subdivisions of the orogen. The aeromagnetic data is consistent with the fan-shape of the orogenic wedge, which could be consistent with either east- or west-dipping paleosubduction, but Zhang et al. (2015) prefer to interpret their data in terms of the east-dipping paleosubduction model of Zhao (2001).

Ishwar-Kumar et al. (2015) present structural and metamorphic data from the Andriamena Complex from the controversial Betsisimisaraka suture in Madagascar since the presence of HP mafic-ultramafic bodies in major shear zones is one of the indicators of paleo-subduction. They document a P–T evolution from 780 C at 24 kbar followed by decompression and cooling, typical of a subduction setting. Pelitic gneisses from the suture zone have protolith ages of 2535–2625 Ma, and a granitic gneiss from the Alaotra Complex has a U/Pb zircon crystallization age of 818 Ma. K–Ar dating of muscovite and biotite from biotite–kyanite–sillimanite gneiss and garnet-biotite gneiss yields ages of 486 ± 9 Ma and 459 ± 9 Ma. These data support the idea that the Betsisimisaraka zone is a Neoproterozoic suture and correlate it with the Kumta and Mercara sutures in India.

Saito et al. (2015) describe the geochemistry of accreted metavolcanic rocks from the Neoproterozoic Gwna Group of Anglesey–Lleyn, NW Wales, interpreted as an accretionary complex with coherent and incoherent (mélange) units composed of offscraped ocean plate stratigraphy (OPS) that includes basalt, bedded chert, red claystone, and trench turbidites. The basalts have experienced hydrothermal alteration and greenschist facies regional metamorphism. Most basalts preserve light REE-enriched pattern in CI chondrite-normalized spider diagrams in within-plate basalt (WPB) fields, whereas others have flat patterns in spider diagrams in mid-oceanic ridge basalt (MORB) fields. The former are interpreted as fragments of ocean-island-basalt volcanism. This represents the first evidence of OIB in a Neoproterozoic accretionary complex of the Gwna Group in Anglesey–Lleyn. The fact that the basalts are capped by hematite-rich claystones indicates that the Neoproterozoic ocean had fully oxic pelagic conditions around ocean islands. This is in contrast to the deep ocean, which was anoxic as shown by the black mudstone overlying the MORB-like metabasalts.

4. Structural and metamorphic evolution of orogens

Five papers address different aspects of the structural and metamorphic evolution of orogens of all ages. Lin et al. (2015) look at Early Cretaceous extensional structures superimposed on older structures of the Dabie-Sulu orogen in eastern China. This Early Cretaceous event was characterized by a short fast cooling period at 130–120 Ma, and superimposed structures on the Early Mesozoic HP/UHP orogenic belt that extensively changed the architecture of this orogen. The structural style changes from west to east: the central Tongbaishan massif is a metamorphic core complex expressed by an A-type non-cylindrical antiform, the central Dabieshan massif has the characteristics of a typical Cordilleran core complex with a migmatitic core, and the Southern Sulu UHP massif is a "wedge-shaped" structure exhumed along a simple detachment fault. The Early Cretaceous extensional zone along the HP-UHP orogen could be part of a vast crustal extensional belt which is widespread in eastern Eurasia continent distributed from Trans-Baikal to the central part of the South China Block. Removal of the sub-continental lithospheric mantle beneath the North China and Yangtze cratons (e.g., Kusky et al., 2014; Li et al., 2015) could have been caused by convective erosion or delamination, and is temporally related to this extension event.

De Jong et al. (2015) discuss the tectonic cause of a Late Triassic magmatic and metamorphic pulse on the southern Korean Peninsula. Regionally this event lasted from 243–220 Ma, but De Jong et al. (2015) report precise ages of 231.4 ± 0.8 and 228.9 ± 0.8 Ma on single grains of detrital muscovite from Jurassic sandstones, similar to reported ages from the Deokjeongri Gneiss Formation, the Weolhyeonri Complex, mid-Paleozoic turbidites, and from the Gyeonggi Massif and Hongseong Belt. De Jong et al. (2015) suggest that this thermal pulse may be related to post-collisional delamination of the lower crust and uppermost mantle, and/or oceanic slab break-off, which is also suggested by almost coeval, widespread mantle-sourced Mg-rich potassic magmatism.

Garde et al. (2015) examine post-Hercynian cataclasis in the Ivrea Zone, Italy, including indentation structures, microtectonic escape structures, microcataclastic injectites and rare true pseudotachylytes. Structural analysis reveals that these structures formed in a pure shear regime, different from prevailing models for Ivrea which assume the presence of lower-crustal, originally flat-lying extensional shear zones, sideways block rotation and exposure of the petrological Moho. The widespread in-situ cataclasis is interpreted by Garde et al. (2015) as due to coseismic deformation by high-frequency seismic waves generated by earthquakes along the Insubric fault, and exerting oscillatory compression, dilation and torsion in a ≤10 km wide zone along the footwall of the Insubric line.

Fujisaki et al. (2015) examine the Ocean Plate Stratigraphy (OPS) of the Ordovician Ballantrae Complex in SW Scotland, and use the stratigraphy and structure to infer the pelagic deposition rate and forearc accretion in the closing Iapetus Ocean. A sequence of basalt, chert, mudstone and sandstone (the Ballantrae Complex) is interpreted as an accretionary prism that is associated with the classic Ordovician Ballantrae ophiolite. Fujisaki et al. (2105) divide the complex into 11 units, and separate zircons from 9 tuff beds in 6 of these units. All are early to middle Ordovician in age, consistent with the radiolarian and graptolite ages, and together with the structure, show that the OPS has been repeated by bedding parallel thrusts, such as found in modern accretionary prisms. The ages of tuffs were used by Fujisaki et al. (2105) to calculate the depositional rate from bedded cherts to be 0.6–3 mm/year, which is similar to Mesozoic–Cenozoic equivalents. The sandstones were deposited near an inter-oceanic island far from any Precambrian source at 477–464 Ma, then accreted to the Ballantrae intra-oceanic arc.

Keulen et al. (2015) describe the shock melting of K-feldspar and interlacing with cataclastically deformed plagioclase in granitic rocks at Toqqusap Nunaa, southern West Greenland, and discuss its implications for the genesis of the Maniitsoq structure. They describe detailed microstructures of quartz, plagioclase and K-feldspar from folded sheets of Mesoarchaean, leucocratic plagioclase-K-feldspar-mesoperthite-bearing orthogneisses in the Toqqusap Nunaa area of the Maniitsoq structure. K-feldspar forms dispersed, highly irregular grains with numerous cusps and saddles, indicating almost ubiquitous direct (shock) melting of the K-feldspar. Direct melting of K-feldspar, but no whole-rock melting, requires shock metamorphism with a short-lived temperature excursion above the melting temperature of K-feldspar (~1300 °C). The feldspar microstructures in the leucocratic orthogneisses of the Toqqusap Nunaa area thus confirm that the recently discovered Maniitsoq structure represents the deep-crustal remnants of a giant Mesoarchaean meteorite impact.

5. Tethyan and Paleo-Asian tectonics and the Central Asian Orogenic Belt

Wilde (2015) reviews the evidence for the final amalgamation of the Central Asian Orogenic Belt (CAOB) in NE China, and tests whether it is related to closure of the Paleo-Asian Ocean or Paleo-Pacific plate subduction. He reviews the history of the CAOB from the Neoproterozoic to the late Phanerozoic during which time the Chinese cratons and intervening accretionary complexes and arcs collided with Eurasia and formed the CAOB. In NE China the Paleoasian ocean closed along the Solonker-Xar-Moron-Changchun-Yanji suture probably by the late Permian, but he suggests that some activity continued until the Triassic, similar to earlier studies along the South Tianshan-Solonker suture (Xiao et al., 2015). Thus, there is overlap between the time of the closure of the Paleo-Asian Ocean and the start of subduction of the Paleo-Pacific plate at 260–250 Ma, with a switch to EW-directed processes. By the Early Jurassic, events associated with the westward advance of the subducting Paleo-Pacific plate dominated the geological evolution of eastern China, leading to extensive development of I-type granites as far inland as the Great Xing'an Range. From ~140 Ma, the Paleo-Pacific plate rolled-back eastward, resulting in an extensional setting in the Early Cretaceous, the effects of which were enhanced by regional thinning of the lithosphere, commonly attributed to delamination. The eastern Asian margin was tectonically complex throughout this period. The north–south oriented Jiamusi–Khanka (–Bureya) block was rifted away from the eastern margin of the CAOB in the Late Triassic, but was then re-united in the Jurassic by westward-advancing subduction that affected both the western and eastern margins of the block. Wilde (2015) shows that accretionary complexes continued to evolve in the Cretaceous along the whole eastern margin of Asia, with final accretion of the Nadanhada Terrane (part of the Sikhote–Alin accretionary terrane) with the CAOB at ~130 Ma, followed by the emplacement of S-type granites

Tian et al. (2015) examine the Triassic deformation of Permian-Early Triassic arc-related sediments in the Beishan orogenic collage (NW China) and relate this to a last pulse of the accretionary orogenesis in the southernmost Altaids. Since the closure time of the Paleo-Asian Ocean is controversial, Tian et al. (2015) use field mapping, structural analysis, sedimentology, geochemistry, and regional age distributions to show that the Hongyanjing Basin is a Permian-Early Triassic inter-arc basin developed between the Carboniferous Mazongshan arc to the north and the Ordovician to Permian Huaniushan–Dundunshan arc to the south. Tian et al. (2015) show that the active continental margin or continental arc on which the Hongyanjing arc-related basin sat was independently distributed in the Paleo-Asian Ocean without any major contribution of provenance from the Tarim Craton and Dunhuang Block to the south and Southern Mongolia accretionary system to the north. Accretionary orogenesis in the Beishan part of the southernmost Altaids was still ongoing in the early to middle Triassic, and it finished in the Late Triassic, which might have been the last pulse of the accretionary orogenesis in the southernmost Altaids (Xiao et al., 2015). Tian et al. (2015) correlate this terminal event with tectonic events in the Kunlun and Qinling orogens in the Tethyan domain.

Fan et al. (2015) examine Triassic mafic blueschists from the Lancang (Paleotethyan) tectonic belt in SW China. The mafic blueschists in the Lancang accretionary complex provide a critical record of Paleotethyan subduction preceeding collision, and Fan et al. (2015) present a set of new petrologic, geochronological and geochemical data for the Suyi mafic blueschists in the Lancang metamorphic zone. The mineral assemblage reveals a prograde path from 0.5 to 0.9 Gpa and a retrograde overprinting back to 0.6 GPa, all within a temperature range of 300–450 °C. The blueschists have a zircon U–Pb age of 260 +/− 4 Ma, and glaucophane yields an $^{40}Ar/^{39}Ar$ age of 242 +/− 5 Ma. The mafic blueschists have OIB chemistry and are suggested to have formed at 260 Ma in a basaltic seamount, then subducted to 30–35 km beneath the Lincang arc forming the epidote blueschists at circa 242 Ma, then transported to shallower levels (and eventually the surface) during continuous underthrusting of the subducted slab.

Yin et al. (2015) describe the petrogenesis of Early-Permian sanukitoids from West Junggar, Northwest China. Sanukitoids are rare subduction-related rock types that have been found in modern arc settings and in Late Archean sequences. Yin et al. (2015) present zircon U–Pb and Ar–Ar ages and major element, trace element, and Sr–Nd–Hf isotope data for the early Permian Bieluagaxi dioritic pluton and dikes from the southern part of West Junggar, which show a remarkable geochemical affinity with Cenozoic sanukitoids of the Setouchi Volcanic Belt of SW Japan. They suggest that they were generated by partial melting of subducted sediments, and subsequent melt-mantle interaction. Yin et al. (2015) infer that the sanukitoids of West Junggar indicate anomalous thermal activity, and suggest that the cause may be ridge subduction, which may have played a significant role in the evolution and growth of the continental crust of central Asia.

Zhou et al. (2015) use stratigraphic and geochronologic data to constrain the emplacement time of the Hegenshan ophiolite in the Central Asian Orogenic Belt. The Hegenshan ophiolite is considered to mark a suture zone, called the Hegenshan-Heihe suture, but the timing of formation of this suture and emplacement of the ophiolite have been controversial. The ophiolite is unconformably overlain by a series of Paleozoic strata, and Zhou et al. (2015) have obtained precise U–Pb ages from these strata to constrain the depositional (post-emplacement) ages. Detrital zircon U–Pb ages cluster at 285–272 Ma (with the peak at 279 Ma), 315–288 Ma (with a peak at 300 Ma), 320–358 Ma (with a peak at 336 Ma), and 406 ± 3 Ma, of which the ~ 280 and ~300 Ma age groups are remarkably similar to those of A-type granites, which formed under a post-collisional setting. The 320–358 Ma zircons show features of mafic-ultramafic zircons in CL images, and are most likely derived from local mafic-ultramafic rocks of the Hegenshan ophiolite. Based on these data, Zhou et al. (2015) propose that the emplacement time of the Hegenshan ophiolite happened before the Middle Permian (~280 Ma), most likely between 300 and 335 Ma, not in the Silurian, Devonian or Mesozoic as previously considered.

De Pelsmaeker et al. (2015) examine the Late-Paleozoic emplacement and Meso-Cenozoic reactivation of the southern Kazakhstan granitoid basement. The Ili-Balkhash Basin in southeastern Kazakhstan is located at the junction of the actively deforming mountain ranges of western Junggar and the Tien Shan, in the southwestern Central Asian Orogenic Belt, and its basement includes a complex assemblage of Precambrian microcontinental fragments, magmatic arcs and accretionary complexes. De Pelsmaeker et al. (2015) dated eight samples of granitoids and tuffs from the Ili-Balkhash area, with zircon U–Pb LA-ICP-MS and these yielded Carboniferous to Late Permian (~350–260 Ma) crystallization ages. De Pelsmaeker et al. (2015) interpret these ages as reflecting the transition from subduction to post-collisional magmatism, related to the closure of the Junggar-Balkhash Ocean during the Carboniferous-Early Permian and hence, to the final Late Paleozoic accretion history of the ancestral Central Asian Orogenic Belt. Apatite fission analysis reveals several later pulses of uplift, including late Mesozoic reactivation related to Cimmerian collisions at the southern Eurasian margin and possibly of the Mongol-Okhotsk Orogeny in SE Siberia during the Jurassic–Cretaceous. Late Cenozoic (17–10 Ma) reactivation is regarded as a response to the India-Eurasia collision.

6. Supercontinent cycle and earth history

Grenholm and Sherstén (2015) present a novel conceptual hypothesis for Proterozoic-Phanerozoic supercontinent cyclicity, with implications for mantle convection, plate tectonics and Earth system evolution, based on the repetitive behavior of C and Sr isotopes in marine carbonates and U–Pb ages and εHf of detrital zircons seen during the Neoproterozoic-Paleozoic and Paleoproterozoic Eras. They assume that these records reflect secular changes in global tectonics, and they then hypothesize that the repetitive pattern is caused by the same type of changes in global tectonics. Grenholm and Sherstén (2015) speculate that there were Paleoproterozoic supercontinents equivalent to Rodinia and Pangea, and that Proterozoic-Phanerozoic supercontinents are comprised of two basic types of configurations, equivalent to Rodinia (R-type) and Pangea (P-type). The Paleoproterozoic equivalent of Rodinia is likely the first supercontinent to have formed, and Proterozoic-Phanerozoic supercontinent cycles are therefore defined by R- to P-type cycles, each lasting approximately 1.5 Gyr. Grenholm and Sherstén (2015) use this cyclic pattern as a framework to develop a conceptual model that predicts the configuration and cycles of Proterozoic-Phanerozoic supercontinents, and their relation to mantle convection and Earth system evolution.

Safonova et al. (2015) consider the generation of hydrous-carbonated plumes in the mantle transition zone and possible links to tectonic erosion and subduction. It is well-established that subduction at Pacific-type margins supplies hydrated-carbonated oceanic crust and continental crust materials down to the deep mantle, which accumulate in the mantle transition zone. Subduction of intraoceanic arcs and subduction erosion of convergent margin hanging walls supplies additional material to the mantle transition zone. Water and CO_2 from these subducted carbonatized sediments and serpentinites form dense hydrous magnesium silicates. The water and carbon dioxide present in the transition zone can metasomatize it and trigger generation of hydrous carbonated plumes. Those hydrous carbonated plumes are suggested to induce melting of metasomatized mantle and subducted MORB slabs to produce hydrous-carbonated melts, which can efficiently penetrate through the mantle. Safonova et al. (2015) speculate that these plumes can result in mantle upwelling, melt ascent, surface rifting and formation of mafic and bi-modal volcanic series. Surface manifestations of hydrous carbonated plumes generated in the transition zone are represented by the numerous Meso-Cenozoic intra-plate volcanic fields of Central and East Asia.

Sato et al. (2015) report the redox condition of the late Neoproterozoic pelagic deep ocean using 57Fe Mössbauer analyses of pelagic mudstones from the Ediacaran accretionary complex in Wales, UK. The mudstones are part of an ocean plate stratigraphic (OPS) sequence that includes mid-ocean ridge basalt, bedded dolostone, black mudstone, hemipelagic siliceous mudstone, and turbiditic sandstone, in ascending order. The youngest detrital zircons in the uppermost sandstones are 564 Ma placing a limit on the age of the sequence showing that it is Ediacaran. The black mudstone contains pyrite without hematite whereas the red claystones (older than 542 Ma) contain hematite as the main iron mineral. These deep-sea mudstones in the Lleyn Peninsula record a change of redox conditions on the pelagic deep-sea floor during the Ediacaran. The black mudstone shows that deep-sea anoxia existed in the late Ediacaran. The eventual change from a reducing to an oxidizing deep-sea environment likely occurred in the late Ediacaran (ca. 564–542 Ma).

To Brian, of course!

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