

Saskatchewan Geological Society Talk

Thursday, January 22nd

**Dr. Jean Bédard, Geological Association of Canada,
Howard Street Robinson Lecturer**

**Continental Drift on Subductionless Stagnant Lid
Planets, the Archaean Earth and Venus**

**Ramada Hotel, 1818 Victoria Avenue, Regina
Canadian North Room, 2nd Floor**

Lunch: 11:45 a.m.

Meeting talk: 12:15-1:00 p.m.

For lunch the cost is:

Members: \$15.00

Student Members: \$5.00

Non-Members: \$20.00

For those not having lunch the talk is free

**Please contact Murray Rogers at murray.rogers@gov.sk.ca or 306-787-1932
before noon, Monday, January 19th if you are going to have lunch.**

If you want lunch please RSVP or you may go hungry.

Continental drift on subductionless stagnant lid planets, the Archaean Earth and Venus

Modern subduction zones have lithofacies and geochemical signatures that differ from those of Archaean terrains. Linear volcano-plutonic island arcs and continental arcs develop above the locus of slab degassing/melting during subduction. Modern constructional arc strato-volcanos are surrounded by tuff-lahar aprons and commonly erupt abundant andesitic lavas. Yet andesitic lavas are among the least common component of Archaean greenstone belts and Archaean lahar deposits are almost unknown. Phanerozoic arc magmas also show characteristic trends on the Th/Yb vs Nb/Yb diagram of Pearce (2008, *Precamb. Res.* V.100 p.14-48) that are parallel to the OIB/MORB array. These trends are attributed to pre-melting metasomatism of the mantle wedge by fluids/melts released from the subducting slab. In contrast, most Archaean lavas define oblique arrays on this diagram, indicating assimilation-fractional crystallization processes, with the felsic mixing pole resembling typical Archaean felsic plutons and volcanics. Phase equilibrium data and trace element modelling imply that Archaean felsic melts can be generated by remelting local tholeiitic basalts at a variety of pressures. High P/T metamorphic rocks (blueschists) only occur in subduction zones but are absent from Archaean terrains, suggesting the absence of Archaean subduction. Ophiolites decorate the sutures of Phanerozoic orogens and most Thethyan type ophiolites are thought to form when an oceanic slab that was dragging down the continental plate detaches, allowing buoyant continental material to rebound and lift the upper plate oceanic lithosphere into place. This obduction mechanism should have operated if there was modern-style subduction in the Archaean. Considered in aggregate, the evidence implies that there was no modern-style subduction in the Archaean.

The komatiites and tholeiitic basalts that dominate Archaean greenstone belts are most plausibly generated above hot mantle upwellings or plumes. The high magmatic flux from the mantle, coupled with a higher radiogenic heat production pre-2.5 Ga, provide the heat needed to rework older rocks and generate the TTG to granite plutons that dominate the Archaean crust. Such a maturing oceanic plateau model involving basal anatexis and recycling is more consistent with the evidence noted above. This scenario also better explains the intimate and repetitive interbedding of mafic-ultramafic and felsic magmas and the commonly proximal volcanic facies than do arc+plume models. The ongoing magmatic flux from plumes would also contribute to softening of the lower crust, and create the archetypal Archaean granite-greenstone dome-and-keel architecture by triggering partial convective overturn.

Although evidence for subduction and seafloor-spreading in the Archaean is equivocal to absent, many Archaean terrains exhibit fabrics formed by bulk shortening and some cratons contain terranes with contrasting histories. Given the absence of evidence for Archaean subduction, what could be a plausible driving force for compression and terrane accretion? Bédard et al. (2012, *Prec. Res.* v. 229, p.20-48) proposed that cratonic mobilism in response to mantle convection currents offers a solution to this paradox. Once a proto-craton develops a deep high-viscosity mantle keel it would become subject to pressure from mantle currents and could drift. Immature cratons or oceanic plateaux would not have a strong mantle keel and so would be static. So we propose that Archaean cratons were the active tectonic agents, accreting basaltic plateaux and other proto-cratons as they migrated across the planetary surface. Accreted terranes and structures indicating bulk shortening would be concentrated at the cratonic leading edge, with oblique and strike-slip shear zones at the sides, extension and possible seafloor-spreading in the lee, and major oblique-slip shear zones in the interior. Overridden oceanic crust would be thrust (subcreted) deep enough to melt in the garnet field and generate syntectonic pulses of tonalite-trondhjemite-granodiorite (TTG), contributing to craton growth and stabilisation.

This continental drift model is not equivalent to modern plate tectonics, because of the absence of subduction. Similarities between Archaean and Phanerozoic magmas and tectonic styles result because modern continents also drift in response to mantle currents, not plate boundary forces as commonly assumed. Active advances of continental masses over unusually thick or buoyant oceanic crustal

segments result in flat-slab subduction, and typically enhance uplift and deformation. Compressional thickening and anatexis of the base of the thickened upper plate crust in such regions leads to localized generation of high-Sr/Y high-La/Yb TTG-like magmas similar to Archaean ones.

Venus is presented as an analogue for a non-plate-tectonic Archaean Earth and structures similar to those observed in the Superior Craton are interpreted from radar images (Harris & Bédard, 2013). On Venus, anastomosing rifts link coronae interpreted to form above upwelling mantle plumes. Lakshmi Planum highland plateau in the western Ishtar Terra region of Venus lacks extensive, regional-scale internal deformation structures and resembles a continent on Earth. A fold-thrust belt produced mountains on its northern margin, rift zones are present along its southern margin, folds and sinistral strike-slip faults occur on its NW margin, and both regional dextral and sinistral strike slip belts occur in a zone of lateral escape to its NE. The scale and kinematics of structures in western Ishtar Terra closely resemble those of the Indian-Asia collision zone, despite the absence of evidence for subduction (trenches and volcanic arcs) or seafloor-spreading (volcanic ridges and transforms) on Venus. We propose that lateral displacement of 'craton-like' highlands on Venus result from mantle tractions at their base in a stagnant lid convection regime, a regime which preceded development of plate tectonics on Earth.

In the southern and western Superior Craton in Canada, the formation of granite-greenstone sequences in a plume-related volcanic plateau, and its subsequent deformation, can be generated through geodynamic processes similar to those on Venus without having to invoke modern-style plate tectonics. 3D S-wave seismic tomographic images of the Superior Province reveal a symmetrical rift in the sub-crustal lithospheric mantle (SCLM) beneath the Wawa-Abitibi Subprovince, with no evidence for 'fossil' subduction zones. We propose that the S and W Superior craton was partly disaggregated and extensively reworked as a result of the arrival of a major plume swarm at ca. 2750-2720 Ma, with more juvenile 'terranes' like the Abitibi-Wawa being new simatic crust formed as the end-result of extensive lithospheric necking and corrosion of the lithospheric mantle. Subsequently, a shift in mantle convection patterns (or the arrival of a different plume located to the N) caused the deep-keeled Hudson's Bay terrane to drift south and re-accrete the partly-dismembered fragments in N to S sequence. Early rift structures localized subsequent deformation and hydrothermal fluid flow during N-S shortening and lateral escape ahead of the southwardly moving indenter. The geometry of reverse and strike-slip shear zones in the Abitibi Subprovince of the SE Superior Province is similar to that of shear zones developed ahead of the western Ishtar Terra rigid indenter on Venus. Deformation in other Archaean cratons previously interpreted in terms of plate tectonics may also be the result of similar, mantle-driven processes.

Harris, L.B., Bédard, J.H., 2013. Crustal evolution and deformation in a non-plate-tectonic Archaean earth: Comparisons with Venus. In: Dilek, Y. & Furnes, H. (eds), *Archean Earth and Early Life*, Springer Verlag. In press.