Article published in the webzine **PlanèteINRS**
http://www.planete.inrs.ca/webzine/abitibi-ressemble-Venus
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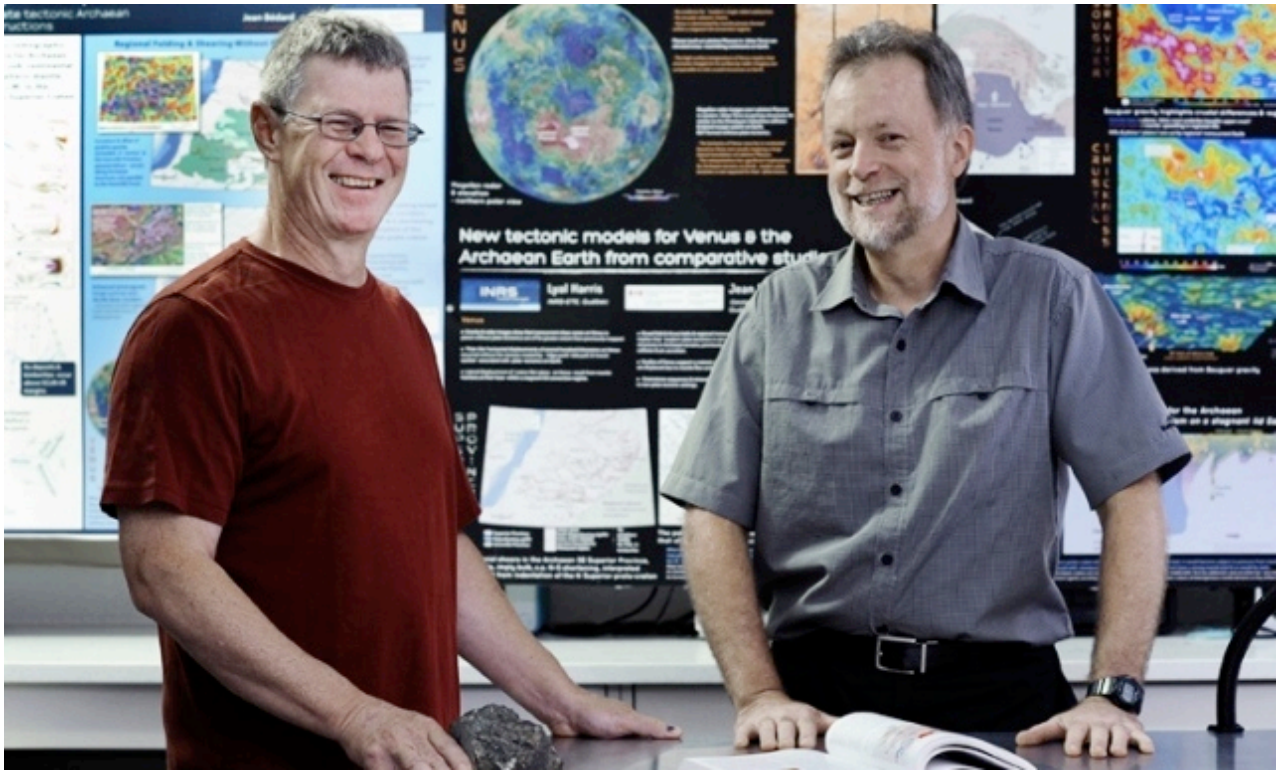
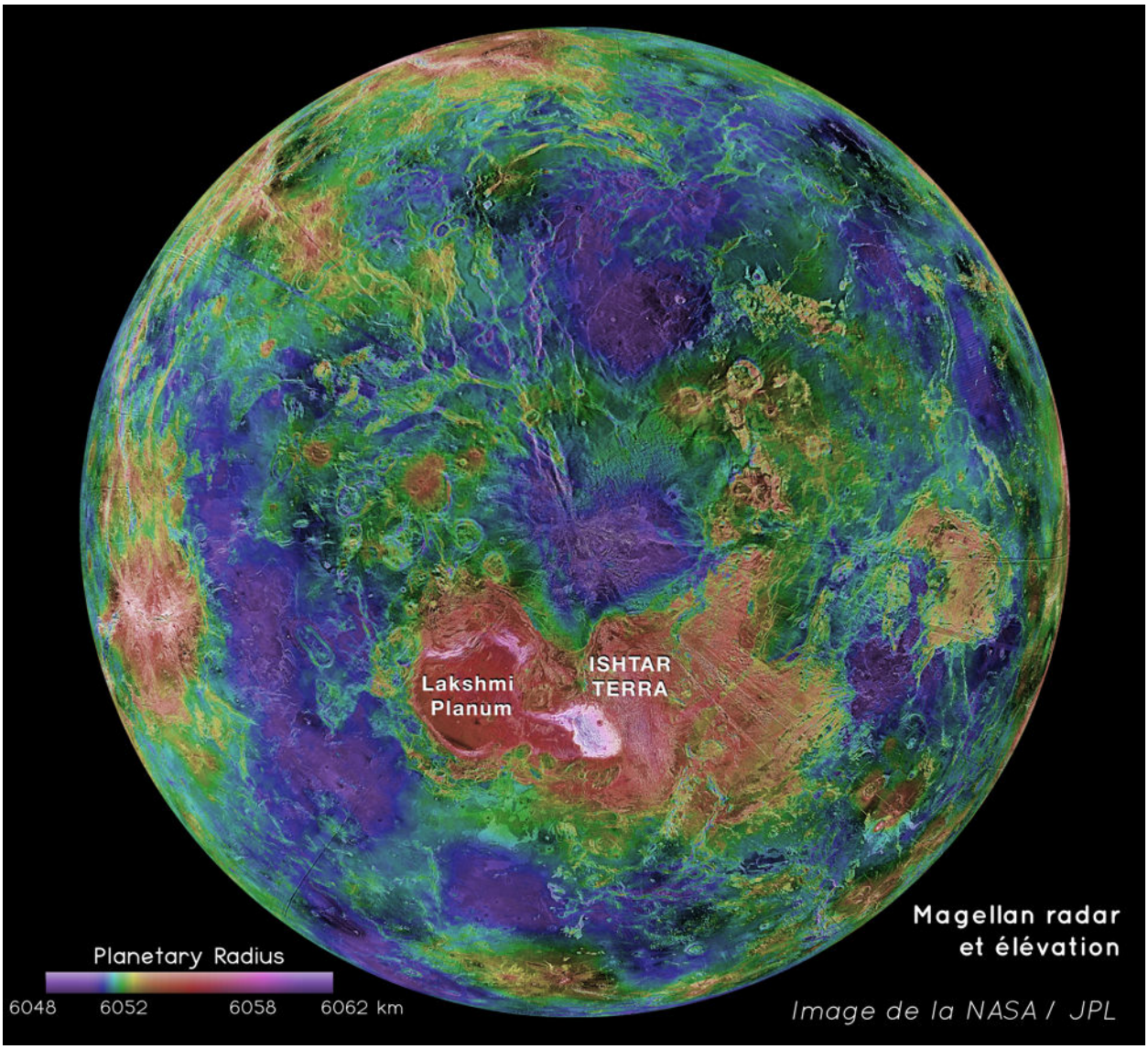
New geological model for the Archaean Earth and Venus

Did the Abitibi Province of Quebec once look like Venus?



The history of science is one of “déjà vus”. In 1915, when the German climatologist Alfred Wegener proposed his hypothesis of continental drift, geologists of the time strongly rejected it, as it was subversive and went against the accepted theories of the time. It was not until the mid-twentieth century that new geological knowledge added support to Wegener's ideas and the theory of plate tectonics was accepted by geologists. A strangely familiar story for Lyal Harris, structural geologist-geophysicist and professor at the Centre Eau Terre Environnement at the Quebec University INRS, and Jean Bedard, a geochemist at the Geological Survey of Canada.

Although plate tectonics provides an explanation for continental drift and the formation of volcanoes and mountain ranges that evolved over periods of hundreds of millions of years, there has been no agreement when this process began on Earth. There is evidence from about the past 2.5 billion years that the continents move through plate tectonics, but following a discovery about the planet Venus, a different tectonic



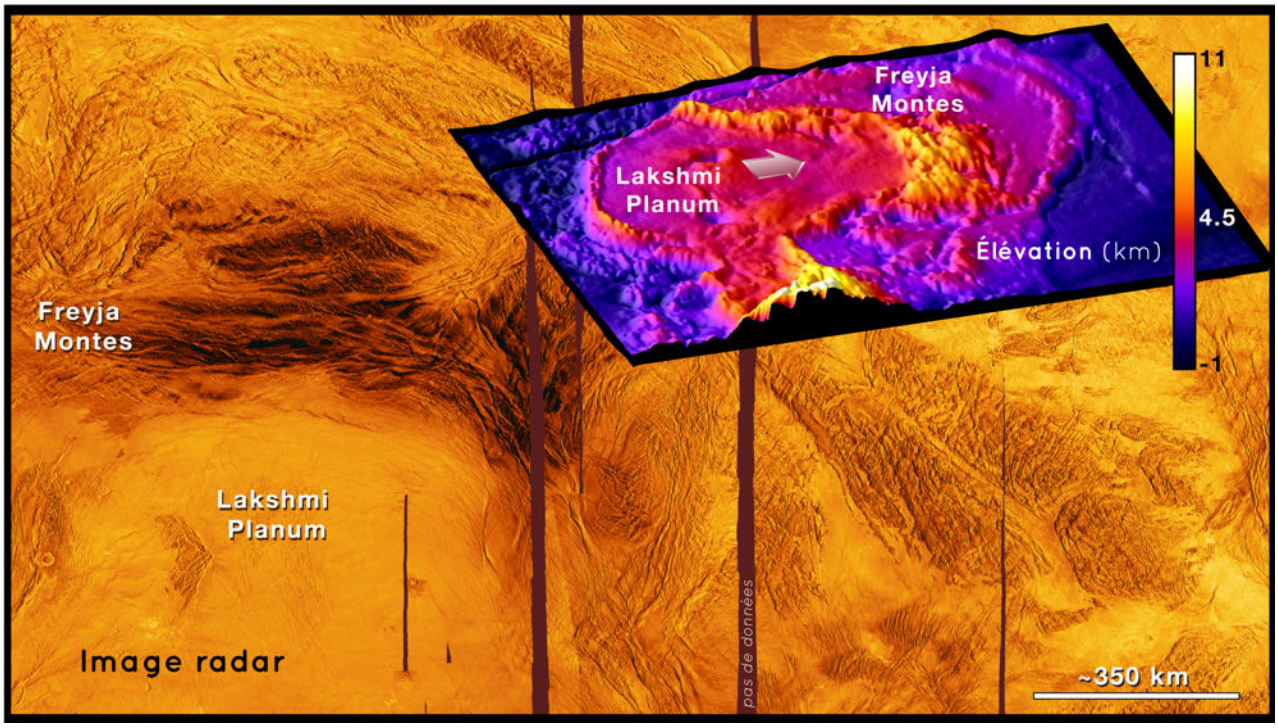
Magellan radar and elevation image. Original image from NASA/JPL.

mechanism has been proposed by two researchers from the Quebec Geoscience Centre. New ideas vigorously debated by many of their colleagues.

To understand the heart of the problem, we must go back to the Archaean, the distant time when our planet was still young. The latest ages suggest that the formation of the Earth goes back to about 4.54 billion years ago. The Archean began later at about 4 billion years (shortly followed by the emergence of the first primitive life) and it lasted for 1.5 billion years.

During this long period the first geological formations preserved on Earth were formed. Today, one can still study some of these old rock formations in Greenland, the Canadian Shield—as in Abitibi, Quebec—Western Australia, and South Africa, for example. "These formations are difficult to study and interpret", explains Lyal Harris, and "more

geophysical data are needed to understand their deep structure". Traces left by ancient volcanic and tectonic activity have been attributed by many researchers to plate tectonics. John and I do not agree".



Magellan radar image of the surface of Venus north of Lakshmi Planum. Mountains and faults resemble the Himalayan system on Earth. The 3D topographic image (inset) reinforces this comparison.
Radar image was enhanced and coloured after an original image provided by NASA through the "Map a planet" web site. 3D image was produced in ImageJ from NASA data.

The mobile Earth
Plate tectonics is the theory that explains continental drift today. Our planet is far from being completely solid: a portion of its interior, the lower mantle or asthenosphere, is viscous, semi-molten in places, and agitated by slow convection currents. The upper mantle and crust constitute the rigid lithosphere which "floats" above. The lithosphere is, however, not continuous and uniform; it is divided into a dozen large plates and other smaller microplates. These plates move against each other: sometimes they rift apart, sometimes they collide, otherwise they simply slide sideways against each other, creating rifts and mountain ranges, or where a plate sinks at subduction zones, volcanic arcs are formed.

"But in the Archean", said Jean Bédard, "there is no evidence that it works the same way. For 30 years studies of old rock formations have sought evidence for plate tectonics at this time, but none has been found. Instead, several fundamental aspects of the geology of the Archean cannot be explained by plate tectonics. We believe that other mechanisms were acting, and it is the work of Lyal on Venus that appear to confirm our hypothesis".

Surprising structural similarities

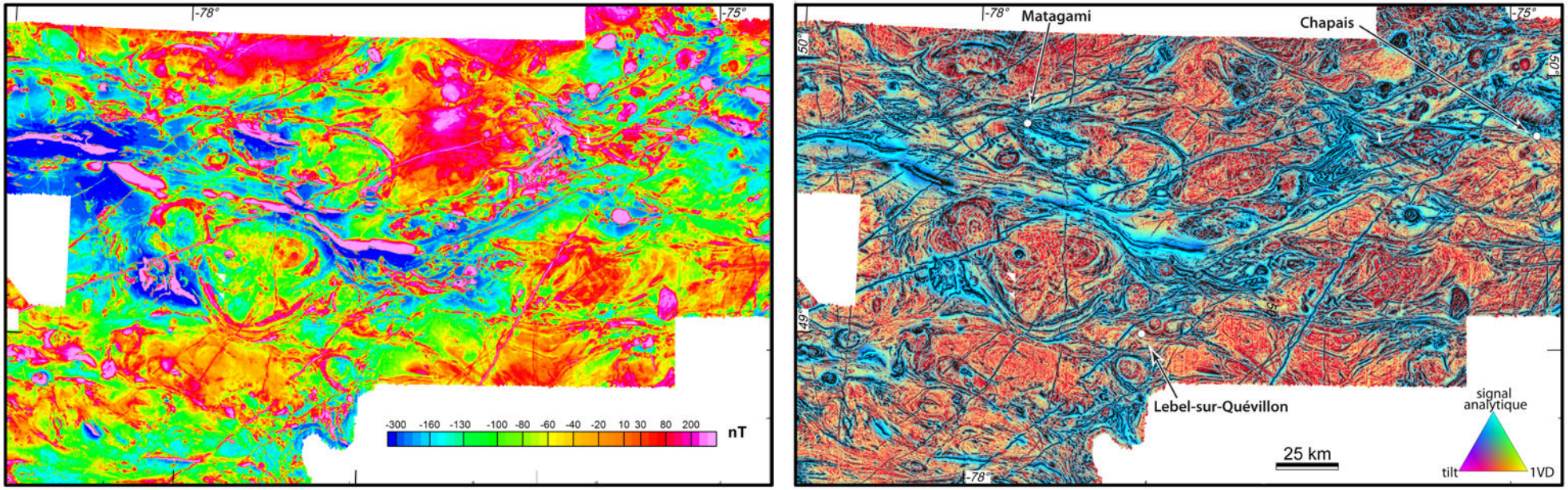
To test their hypothesis, the two researchers had to find a model, a planet where there is no tectonic plates, but where the continents seemed to have moved. These "continents" Lyal Harris found them on Venus. "Between 1990 and 1994, the American space probe Magellan imaged the surface features of Venus using radar and variations in its gravitational field were calculated from tiny changes in the orbit of Magellan. With new tools in geophysics, gravity data of Venus, combined with radar interpretations have led to amazing discoveries on geological structures and tectonic evolution of the sister planet of Earth. We found what we were looking for: regional fault systems that show the movement of thick crustal blocks ("plana"), which resemble terrestrial continents, accompanied by rifts where the crust is thinned. Emphasis is generally considered that this planet does not show signs of tectonic plates as the current Earth".

The most significant region studied is Lakshmi Planum, a large plateau located near the north pole of the planet Venus. By observing the terrain around the plateau, one sees mountain ranges that rise on its northern perimeter. "Compared with the Earth, it is remarkably similar to the situation in India", says Lyal Harris. "The Indian plate, formerly separated from Australia and Antarctica, moved north until it collided with the Eurasian plate. The sediments of the Indian passive margin were folded and overlapped when India was pushed downwards beneath Tibet, forming the Himalayas, including Everest. On the other hand, large faults with lateral movements accompanied the eastward ejection of Indochina".

However, as shown by the reconstructions of continental displacements, the Indian subcontinent has moved faster than other continents generally do. Certainly, plate tectonics has played the most important role, but India seems to have been pushed by something else. "And this other force", suggests Lyal Harris, "could result from a mantle plume, a thermal instability that rises towards the surface. Like a fountain in a public park, the mantle rises and melts and spreads like an umbrella when it arrives at the lithosphere. Such a system may well push a geological mass in one direction and to indent it into another mass, even without the presence of plate tectonics. A similar process is envisaged to explain displacements of Lakshmi Planum on Venus, and to explain the horizontal tectonic motions in the Archean Earth in the model developed by Jean".

In the Abitibi and the geological region of the *Nord-du-Québec* called Opatica, there are Archaean geological structures that of identical geometry to those we see around Lakshmi Planum on Venus. "If our hypothesis is valid", says Jean Bédard, "it will be necessary to completely rethink mineral exploration models, as current predictions are based on modern plate tectonics and our studies suggest that this had not yet commenced at this early stage of the Earth's history"

Are we on the cusp of a paradigm shift?



Aeromagnetic images of the central Abitibi Subprovince of the Superior Craton (Quebec). The initial total magnetic field image (left) was enhanced to better portray geological structures (e.g. right image). The network of folds and shear zones /faults is surprisingly similar to those formed north of Lakshmi Planum (see other images in this article).

(Original Geological Survey of Canada data from the TGI3 program were treated by Lyal Harris)

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Bédard, J.H., Harris, L.B., Thurston, P. (2013) The hunting of the snArc. Precamb. Res. 229: 20–48 http://www.sciencedirect.com/science/article/pii/S0301926812000897

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Article in press

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Posters

Venus http://d32ogoqmya1dw8.cloudfront.net/files/NAGTWorkshops/structure/2014forumuploads/harris_structural_tectonics_fo.pdf

Archaean tectonic model for the Abitibi http://d32ogoqmya1dw8.cloudfront.net/files/NAGTWorkshops/structure/2014forumuploads/harris_amp_beacutedard_structu.pdf