Timing of metamorphism and extension in the western Himalaya: Leo Pargil dome, NW India

J. LANGILLE[1]*, M. JESSUP[1], J. COTTLE[2], G. LEDERER[2] AND T. AHMAD[3]

[1]University of Tennessee, Knoxville, TN 37996, USA (*correspondence: jlangill@utk.edu)
[2]University of California, Santa Barbara, CA 93106, USA
[3]University of Delhi, Delhi -110007, India

The Himalayan orogen is the product of significant crustal shortening and thickening that has occurred since the Eocene and has resulted in major fault systems, such as the Main Central thrust zone and South Tibetan detachment system which accommodated crustal shortening from the Eocene to middle Miocene. In contrast to these older structures, the Leo Pargil Dome, NW India, is a 30-km-wide, northeast-southwest trending antiformal structure bound by normal faults [1] that are interpreted to record the onset of orogen parallel extension in this convergent setting [2, 3].

The Leo Pargil dome is composed of amphibolite facies rocks intruded by multiple generations of variably deformed to undeformed leucogranite dikes and sills. In the deepest structural positions, the injection complex transitions into migmatitic gneiss. The northwest-dipping, 300-m-thick Leo Pargil shear zone records top-to-the-northwest normal-sense shear and separates footwall rocks on the western side of the dome from the low-grade Tethyan Sedimentary sequence in the hanging wall.

New pressure-temperature-time data from the Leo Pargil shear zone and the hanging wall were calculated using THERMOCALC. These data suggest that Barrovian metamorphism occured at ~640 °C and 0.7 GPa in staurolite grade hanging wall rocks. Syn-kinematic staurolite growth during top-to-the-northwest shear on the Leo Pargil shear zone occured at ~590 °C and 0.8 GPa. Monazite U-Th-Pb ages suggest Barrovian metamorphism occurred during the late Eocene to Early Oligocene. Staurolite growth during top-to-the-northwest shear on the Leo Pargil shear zone occured during the late Oligocene. This was followed by injection of multiple generations of leucogranite in the footwall during the early Miocene [4]. These data provide new constraints on the transition from crustal thickening to melting and exhumation in the NW Himalaya.

[1] Thiede *et al*. (2006) *GSA Bulletin* **118**, 635–650. [2] *Jessup et al. (2008) Geology* **36**, *587*–590. [3] Murphy *et al*. (2002) *GSA Bulletin* **114**, 428–447. [4] Lederer *et al*. (2010) *Geochimica et Cosmochimica Acta*, this volume.

Planetary evolution

CHARLES H. LANGMUIR

Earth and Planetary Sciences, Harvard University, Cambridge MA 02138 (langmuir@eps.harvard.edu)

Planetary evoluton relates life, ocean, atmosphere and planetary interior. One asepct is progressively increasing biological access to energy, which may provide a directionality to evolution. Earth began with reduced interior and exterior, and limited energy potential between reservoirs. Reduced external conditions were necessary for the origin of life. A series of energy revolutions changed the oxidation potential of the planet by generating oxidized and reduced reservoirs that form a ‘planetary fuel cell’ that powers modern life and surface processes. First autotrophy, then oxygenic photo-synthesis enhanced the productivity of the biosphere. Storage of organic matter led to gradual rise of oxygen, permitting aerobic respiration that increased energetic productivity by a factor of 18 and led to eukaryotic cells. Continued O_2 production overcame the reduced sinks at the surface to create the global fuel cell with reduced reservoirs of Earth’s interior and organic carbon, and oxdized reservoirs in the ocean and atmosphere. Multicellular life evolved to take advantage of this energy potential. The rise of free O_2 required lessening the oxygen sinks through progressive oxidation of reduced surface reservoirs. O_2 in the atmosphere is trival compared to the vast reservoirs of oxidized Fe and S that have supplied most of the electrons to make organic matter. There is a mass balance problem that more oxidzed atoms than reduced carbon reside at the surface. From mass balance alone, the mantle cannot have become more oxidized over time because it would worsen the mass balance problem, and the mantle’s reduced Fe reservoir is too large. Subduction of reduced carbon is inevitable, particularly in the reduced ancient oceans, and may be the missing reduced reservoir. Today, more oxygen is subducted in the ocean crust than is formed by net organic matter burial. Change in the oxidation of ocean crust owing to the oxidation state of the deep ocean may provide a modern buffer for the oxyenated Earth.

The latest energy revolution is human civilization, which has enhanced energy access by 20-100 times relative to aerobic metabolism. The human energy revolution currently uses the stored solar energy in the planet’s fuel cell, and ultimately will access stellar energy directly through fusion. This is a new stage of planetary evolution equivalent to the invention of aerobic metabolism, and marks a new planetary era. As with other energy revolutions and era boundaries, catastrophe is possible. Only if planets are able to surmount such a crisis are there civilizations elsewhere in the galaxy.