EUG XI

Theme PS

Presidential Lecture and Plenary Sessions

Monday: Presidential Lecture

16:45 Room G9: Erasme Auditorium

PS01 : MOpm36 : G0
EUROPROBE: Multidisciplinary Studies of Continental Lithosphere

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The last decade has seen a widening of collaboration within the European Geoscience community to involve colleagues from all of "Greater" Europe's countries. Within the framework of a European Science Foundation programme, EUROPROBE, many hundreds of Lithosphere Scientists from about thirty countries have been collaborating on a wide range of key research targets that have all involved close integration of geological, geochemical and geophysical investigations. Understanding the lithosphere requires close interaction of the Solid Earth disciplines; in so diverse a continent as Europe, it also involves a variety of inbuilt national traditions and methodologies that are not so easily integrated. Nevertheless, this diversity is proving a strength. EUROPROBE's east-central-west collaboration has been able to exploit not only the latest technologies that sometimes tend to steer western geoscience, but also the outstanding programmes of central and eastern Europe, where deep and super-deep continental drilling and vast long range seismic profiling provide unique information on the continental crust and upper mantle.

EUROPROBE targets range from the young mountain belts of western Europe to the Archaean cores of the East European Craton. They have reached from the Iberian Peninsula to beyond the Urals. Most of the ten projects have focused on orogenic processes through time; rifting of the craton has also been a prominent component of the programme. Comprehensive deep seismic investigations have provided a foundation for many of the geological studies, for example, long deep reflection (CMP) profiles across the southern and central parts of the Urals mountains, DSS profiles across the Baltic States, Belarus and Ukraine (eg. EUROBRIDGE and DOBRE), and the recent acquisation of the vast CELEBRATION and POLONAISE wide-angle experiments in central Europe. Teleseismic tomography has imaged the deep lithosphere, beneath the seismically active Vrancea zona and across the boundary between the East European Craton and the Variscides; it is providing new information on the exceptionally deep (60 km) crustal roots of parts of the Fennoscandian Shield. Electrical conductivity studies (BEAR) are yielding unique information on the Fennoscandian lithosphere-asthenosphere system. Drillholes, several kilometres deep, penetrating the basement beneath the Phanerozoic cover of the craton and marginal orogens, for example, beneath the Pechora Basin, have provided critical geological and geochemical evidence for interpreting the deep crustal structure. Xenoliths are yielding geochemical constraints for interpreting geophysical data on the lower crust and upper mantle, both beneath the Fennoscandian Shield and the young orogens. Integrated analysis of the late Palaeozoic orogens along the eastern (Uralides) and western (Variscides) margins of the East European Craton is providing new insight into the processes of subduction and accretion of ophiolites and island-arc terranes and the growth of continental crust. Palaeomagnetic and palaeontological data are defining Early Palaeozoic Baltica and its movement in relation to other continents. EUROPROBE's interdisciplinary workshops have been essential for integration of the science.

A platform has been established for expanding our European cooperation across the entire Eurasian continent from the Atlantic to the Pacific, far north into the basins of the high Arctic and south into the mountains of the Balkan States. Partnership in science is both the prerequisite and the recipe for success. Earth Science thrives on this continent-wide collaboration.

Tuesday: Plenary Session

12:15 Room G0: Schweitzer Auditorium

PS01 : TUam16 : G0
The Snowball Earth Hypothesis: Testing the Limits of Global Change

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In the 1960's, simple climate models indicated that if ice caps grew to cover half the Earth's surface area, runaway ice-albedo feedback would drive ice lines to the equator and global mean surface temperature would drop to ~225K. The resulting ice-albedo catastrophe would not be irrevocable, as originally believed, but would last for millions of years, until atmospheric CO_2 (built up by volcanic outgassing in the absence of silicate weathering) exceeded 0.1 bar. The resulting greenhouse forcing would raise tropical surface temperature to the melting point, after which deglaciation would proceed violently due to reverse ice-albedo feedback. As the planetary albedo falls, the CO_2–rich atmosphere would create a transient ultra-greenhouse environment. Surface temperatures ~325K in the tropics would drive a strong hydrologic cycle. Carbonic acid rain would react with emergent shelf carbonates, unaltered syn-glacial volcanics and comminuted glacial debris. The resultant alkalinity flux would cause rapid inorganic carbonate sedimentation in warming surface waters. Atmospheric CO_2 would be gradually drawn down by silicate weathering, leading to eventual reestablishment of small ice caps. The global 'freeze-fry' cycle (essentially due to a hysteresis in the path of atmospheric CO_2) has the virtue of making many predictions that can be tested geologically.

Meanwhile, geologists had long been puzzled by many features of the late Neoproterozoic (730-580 Ma) sedimentary record. The salient features were observed world wide, and the match between the observations and the climate-model predictions is remarkable. Glacial deposits are widespread on every continent. Robust paleomagnetic data shows that ice lines descended to sea level near the equator, and remained there through several magnetic polarity reversals. Banded iron-formations (with ice-rafted dropstones) appear for the only time in the last 1.8 Ga, consistent with an ice-covered ocean, consequent deep-water anoxia, and lack of riverine sulfate input. Glacial deposits are overlain sharply by 'cap' carbonates with unusual textures and negative $\delta^{13}C$ values, implying rapid carbonate production in the glacial aftermath. Unusually high $\delta^{34}S$ values for post-glacial marine sulfate suggests prolonged attenuation of riverine input to the ocean during glaciation. None of these features was previously explained, but all follow readily from the snowball hypothesis. Various arguments have been raised against the hypothesis, involving sea-level change, thickness of glacial deposits, $^{87}Sr/^{86}Sr$ records, timing of iron-formation, general circulation models, algal survival, and the fossil record of early metazoa (which appear abundantly only after the last of perhaps four late Neoproterozoic snowball events). Only the last of these arguments has yet to be reconciled with the hypothesis. Joe Kirschvink, who originated the hypothesis, and my colleague Dan Schrag, with whom I have worked closely on every aspect of it, believe that the timing of snowball events in Earth history is ultimately related to unusual distributions of continents and oceans on the globe. The development of the snowball Earth hypothesis is a fine example of Wegener's maxim that "all earth sciences must contribute evidence towards unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combining *all* this evidence"[italics added].

Wednesday: Plenary Session

12:15 Room G0: Schweitzer Auditorium

PS01 : WEam16 : G0
The Geochemical Memories of Mantle Convection

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The paradigm of layered mantle convection was established nearly 20 years ago, mostly based on geochemical mass balance and heat budget arguments. It is now stumbling over the difficulty imposed by convection models to maintain a sharp interface in the mantle at mid-depth and by overwhelming tomographic evidence that at least some of the subducting lithospheric plates are currently reaching the core-mantle boundary. Discontinuities in the deep mantle, the D" apart, remain elusive. A further problem is the increasingly persuasive identification through geochemical means of various ingredients from ancient oceanic lithospheric plates, such as altered oceanic basalts, gabbros and pelagic sediments in the source of hot spot basalts. It is further being argued that ancient oceanic plateaus may also be a normal component of some ocean island basalts, notably those from the EM I clan.

The present situation, however, remains frustrating because the reasons why the layered convection model was defended in the first place are still there and do not find a proper answer with the model of homogeneous mantle convection. First, the imbalance between heat flow and heat production (Urey ratio) requires that the deep mantle is rich in U, Th, and K. Second, the imbalance of some refractory lithophile elements between the composition of the Earth estimated with a homogeneous mantle and the composition of chondrites leaves a number of 'paradoxes' unresolved. Third, convective mixing should take place with a characteristic time of less than 1 Gy and should essentially wipe out mantle isotopic heterogeneities.

It can be shown that, with the possible exception of lead, helium, and argon, the isochron relationships observed for many radioactive systems indicate time constants characteristic of the chemical differentiation of the mantle-crust system and have no chronometric implications. No more than Joly was finding the age of the oceans from the salt contained in seawater and rivers can we infer the age of the Earth from mantle-derived basalts. For all these systems, the mantle is therefore at steady state with 'no vestige of a beginning'. In addition, frustrating evidence that the lower mantle hides a geochemical 'black box', with a non-primitive composition and hardly accessible to observation, is mounting.

The question then arises of the transient between the primary differentiation of the planet 4.5 Gy ago and the modern state of mantle convection. Standard models of mantle convection do not properly address these issues. Evidence for the persistence of any leftover from the primary recipe rests entirely on the blurred signal of rare-gas isotopes and the remains of Early Archean mantle-derived volcanics that suffer preservation problems.

I will argue that, immediately after the early differentiation of the Earth 4.54 Gy ago which, because of a gravity stronger that that of the Moon and Mars, was probably not dominated by a huge magma ocean, mantle convection took off. Plate penetration and convection are strongly influenced by the abundance of plume heads carried by the lithospheric plates. Barren plates penetrate deeper than plates loaded with oceanic plateaus. Mantle heterogeneities are destroyed by convective stirring but permanently renewed by selective plate penetration. Hot spot instabilities have declined over the Earth's history and therefore the layering of the mantle has evolved substantially. Whole-mantle convection may be reconciled with geochemical evidence of modern and ancient basalts through the depth-dependent residence time permitted by selective subduction.