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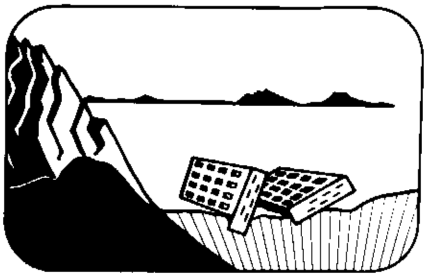

Earth Movement – Causes and Effects

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The 1980 National Conference on Earth Science, sponsored by the Canadian Society of Petroleum Geologists and the Department of Extension of the University of Alberta, was held May 5-8, 1980 at the Banff Centre. The subject of the conference was "Earth Movements – Causes and Effects" and over the four days of the conference the invited speakers dealt with many topics relating to the subject, including a review of the model of plate tectonic, the flexural behavior of the lithosphere and asthenosphere, development of a classification of different basin types and deformation belts, as well as the subject of tectonic processes of planets and satellites. The speakers included R.I. Walcott, Department of Scientific and Industrial Research, Wellington, New Zealand, whose work includes studies of isostasy and flexural behavior of the lithosphere, E.R. Oxburgh, Department of Mineralogy and Petrology, University of Cambridge, co-author of papers on studies of thermal distribution in the crust and lithosphere, A.W. Bally, Shell Oil Company, Houston, well known to Canadian Petroleum Geologists for publications on regional tectonics and the development on sedimentary basins, C. Beaumont, Department of Oceanography, Dalhousie University, whose research includes modelling studies of the rheologic behavior of the lithosphere, and J.W. Head, Department of Geological Sciences, Brown University, a key scientific participant in the NASA planetary geology program including the recent APOLLO program.

The conference provided significant insight into the nature of earth tectonic processes, the evolution of sedimentary basins and tectonic belts, the nature of flexure of the lithosphere in response to loading, the current state of the theory of plate tectonics as a tectonic model, and the heat flow distribution in the crust. While indirectly related to the petroleum exploration business, an understanding of these subjects is a necessary tool for the petroleum geologist in exploring frontier basins, where an understanding of thermal history, tectonic processes and related sedimentation histories provides a framework for high-grading potential exploration plays. The conference provided a fruitful and exciting atmosphere for discussion of these topics.

Walcott began the conference with a discussion of the flexural behavior of the lithosphere and the asthenosphere, terms introduced by Barrel in 1914 to describe the outer, relatively strong layer of the earth and a weaker, inner layer. The lithosphere can be modelled as a thin viscoelastic sheet over a viscous fluid (asthenosphere) and values of the flexural rigidty of the lithosphere (i.e. resistance to bending) have been derived from studies of isostatic rebound.

Oxburgh reviewed the development of the theory of plate tectonics as a global tectonic model. Studies of rates of ridge spreading and subduction around the world have shown great variability in the rates of spreading. The rates of subduction of oceanic lithosphere show a strong mean of about 8.8 cm/year. This relationship suggests that the mechanism of subduction of oceanic lithosphere is of fundamental importance to the understanding of the mechanics of plate tectonics.

Monday afternoon, Walcott continued his discussion of derived estimates of the flexural parameters of the lithosphere and of the time dependence of these parameters. He discussed the relationship between the wavelength of lithosphere flexures, the flexural rigidity of the lithosphere and the thickness of the lithosphere. Estimated thicknesses for the lithosphere have been obtained using this relationship and range from about 110 km for continental lithosphere to about 75 km for oceanic lithosphere. The Basin and Range area however exhibits an anomalously thin lithosphere of about 20 km.

Bally then presented a tectonic description of the world, a review of the paper by Bally and Snelson (1980). Continental margins can be subdivided using crustal characteristics and global earthquake distribution into passive, active, cratonic (entirely on continental crust) and transform (strike-slip) margins. The classification framework is further extended by defining a "megasuture", a predominantly compressional deformation belt characterized by extensive orogenic and associated igneous activity, which can include some extensional tectonics and basin formation. A characteristic feature of megasutures is subduction and both B-type subduction zones (Benioff zones) and/or A-type (Ampferer-type, e.g. foreland thrust and fold belt of Cordillera) may occur.

Oxburgh began the second day with a discussion of some thermal aspects of plate tectonics. He described the manner in which cooling can occur by convection in silicate liquids and developed this into a model of global plate tectonics and mantle convection. He went on to describe the now well known observation that the topographic height of the ocean floor is directly proportional to its age, i.e., oceanic lithosphere cools and sinks as it moves away from the oceanic spreading ridges.

Baily expanded on his previous talk to illustrate a basin classification based on position relative to tectonic belts (megasutures). They can be classified as basins on rigid lithosphere (rifts, cratonic basins), perisutural basins (on rigid lithosphere but adjacent to megasutures) and episutural basins (within megasutures). Examples of all types were illustrated thoroughly. The classification is a simple framework that links the concept of basin development to the plate tectonic model and should prove to be a more useful classification today than the geosynclinal classification of Kay. Of particular interest in the discussion of sedimentary basins was the observation that major unconformity bounded sequences must represent periods of a particular tectonic distribution of the lithospheric plates.

Tuesday afternoon, Beaumont presented the results of modelling studies simulating the behavior of the lithosphere. He reviewed its rheology and inferred composition and pointed out that the "lithosphere" can be defined both on the basis of rheologic properties and temperature boundary conditions. Through the use of olivine deformation maps he illustrated the types of rheologic behavior (cataclastic flow, diffusional and power-law creep, plastic creep) which can be inferred to be important in a flexed slab of foreland basin or migrating foredeep of the Canadian Cordillera. The model simulates the formation of the foreland basin at the site of downward flexure of the lithosphere in response to passive loading by the advancing deformation front of the fold-thrust belt during Upper Jurassic to Eocene time. Addition of clastic wedge sediment into the basin from the core of the thrust belt leads to further depression of the lithosphere. Theoretical structure sections generated by the model, assuming a Maxwell viscoelastic lithosphere, agrees closely with actual structure sections taken from published sources both in the shape of the lithospheric flexure and the magnitude of the clastic wedge prism generated. Predicted shale compaction and thermal metamorphism of coal also agree closely with observed figures.

Wednesday, Oxburgh discussed Temperatures in the Lithosphere, including the factors controlling temperature distribution and heat flow in a steady-state model and the effects of processes such as uplife, rapid burial, tectonics (thrusting) and magmatic emplacement in producing perturbations in a steady-state model. The thermal conductivity of various rock types and the concept of "thermal resistance" of a rockpile, i.e., the sum of the ratio of thickness to thermal conductivity for each part of the rockpile, was introduced and illustrated with an example from the North Sea.

Bally continued his discussion of world tectonics with a description of the geology of Tibet and China. He reviewed the geology of the ophiolite complex overthrusted onto folded Cretaceous clastics along the Yalu-Tsampo suture, and described briefly the complex north and south facing suture systems which occur in China.

Wednesday afternoon, Walcott reviewed recent work in New Zealand correlating seismicity and geodetic strain measurements. Early triangulation survey data was used to calculate large scale geodetic strains within the 70 - 100 km wide axial tectonic belt. This belt traverses the North Island, where it overlies a shallow northeast dipping subduction zone, and the South Island, where it follows the trace of the Alpine Fault zone. Compression was normal to the belt prior to a major earthquake in 1931 in the Hawkes Bay area of the North Island. Subsequent strains indicate extension normal to the belt. When linked with earthquake focal mechanisms, the strain history is best explained by a model of oblique subduction of oceanic crust with interrelated strike-slip and dip-slip components. Periodic locking of the subduction thrust leads to strain build-up and subsequent major earthquakes which accompany decoupling of the plates across the subduction thrust. Strain measurements on the South Island indicate deformation axes which support the published rotational pole for the Indian-Pacific pair. Also strain across the Alpine fault indicates displacement oblique to the fault trace, i.e., compression across the fault has led to the rise of the Southern Alps.

Thursday, Oxburgh reviewed the thermal evolution of the ocean basins and continents. He discussed the direct relationship of heat flow and age for continents and ocean basins, and the similar relationship between heat flow and the thickness of the lithosphere. He then reviewed a model for formation of a stratified oceanic lithosphere comprising a layer of basaltic rock, a layer of depleted mantle (Harzburgite) and a layer of undepleted mantle. Melting of this stratified lithosphere during subduction gives rise to updwelling of less dense depleted material as intrusions in a back-arc envirnoment.

Finally, Head reviewed the results of the NASA planetary geology program. He examined in detail the topographical features (highland areas, impact features, linear rilles, sinuous mare ridges) which are observed on the moon. He discussed the composition of samples recovered by the APOLLO program, gabbroic anorthosite from highland areas, multi-cycle impact breccias, and mare floor deposits which comprise primarily flood-type basalts which often contain high percentages of titanium. The evolution of the moon is interpreted to have progressed from differentiation of the crust, through periods of high rates of bombardment to more recent formation of linear rilles (graben-like?) and mare (compression?) ridges during periods of lower rates of bombardment. He then extended his discussion to observation of features of the other planets, Venus, Mercury, Mars and Jupiter. Initial observation lead to speculation that the study of Venus may provide significant insight into the early evolution of the earth. The tremendous amount of technical data gathered by the NASA scientists provides an awesome insight into this frontier science of planetary geology.

The conference was followed by a "Trans-Cordilleran Field Trip" led by R. A. Price, Department of Geological Sciences, Queen's University, and J. W. Monger, Geological Survey of Canada.

The conference and field trip served well their purpose of bringing together interested and knowledgeable industry people with recognized scientific figures to study and the subject of Earth Movements – Causes and Effects.

References

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