BOOK REVIEW

PROTEROZOIC GEOLOGY

1. EARLY PROTEROZOIC GEOLOGY OF THE GREAT LAKES REGION : Mem. No. 160, (1983) Geological Society of America, 148 pp. price : $ 28 inclusive of postage.
2. PROTEROZOIC GEOLOGY : Selected papers from an International Proterozoic Symposium. (Editors) L. C. Medaris, C. W. Byers, D. M. Mickelson and W. C. Shanks. Geological Society of America, Mem. No. 161 (1983) 315 pp. Copies available from 65A Book Sales P.O. Box 9140, Boulder, Colarado 80301.

The two volumes under review are the result of an International Proterozoic Symposium held at the University of Wisconsin in May 18 to 21, 1981 to celebrate the centennial of the Department of Geology and Geophysics of that University. The editors in the Preface state that the Symposium focussed on the Proterozoic era because of the important role of Proterozoic events in the geological development of the Earth and also because of the fact few modern comprehensive publications are available on the subject.

(1)

The earlier of the two volumes (Memoir 160) is devoted to a detailed description of the early Proterozoic history of the Great Lakes region of the United States of America, and is of more than local interest. Penokean orogeny which represents the most extensive and significant event occurring around 1800-1900 m.y. is the subject matter of this Memoir. Out of the 9 papers included in the volume, the first seven deal with Penokean orogeny while the last two describe different aspects of Early Proterozoic (1760 m.y.) felsic magmatism and the deposition and significance of red quartzites.

A closer acquaintance with the geology of one of the very important Early Proterozoic fold belt of the Great Lakes region is of importance as it helps in getting a clearer picture of events which have characterised the transition from Archaean conditions to those of Proterozoic. The Penokean belt described in this Memoir is as much as 250 km wide and represents a zone of deformed and metamorphosed sediments of Early Proterozoic formed in an intra-cratonic rifted basin. Deformation was complex involving extensive participation of basement rocks. An extensional stage, during which the Early Proterozoic rocks were formed, was followed by a compressional stage leading to deformation. Following stages in the development of the basin have been traced : (1) Graben stage, (2) Regional downwarping, (3) Restricted deposition and flysch stage followed by (4) Orogenic deformation, intrusion and metamorphism.

Those who are engaged in the study of Proterozoic basins in other continents, especially those successions which belong to the Early Proterozoic which are very much deformed, will find these papers extremely interesting. They could serve as models for carrying out similar studies elsewhere. Tectonic models proposed for the development of Early Proterozoic basins will be of particular interest.

(2)

The second volume (Memoir 161) is more interesting to us in India as it deals with the larger aspects of Proterozoic Geology. Papers included in the volume have

been grouped into five broad sections: (1) Tectonics, (2) Magmatism and metamorphism, (3) Mineral deposits, (4) Life and (5) Glaciation.

All papers included in the volume are of the nature of review papers covering a great deal of recent research and are presented in a very lucid style. Reviewers are themselves experts in their fields of specialization and the result of their combined effort is a very satisfying document surveying events during a period which constitutes nearly 50 per cent of the geological record.

Tectonics

The tectonic section covers much familiar ground. B. F. Windley in his review presents evidence for the continued formation of greenstone and granulite-gneiss terranes even during the Proterozoic, although on a reduced scale and argues that these should be seen as a continuing tectonic form throughout the middle part of Earth's history. J.D.A. Piper reiterates his belief in the existence of a super continent in Proterozoic. Rarity of mafic volcanic rocks and their presence as interstratified layers within sediments, absence of layering and sheeted dykes, make A. Kroner discount operation of plate tectonic closure and subduction of oceanic lithosphere in Proterozoic. He advocates an alternative model which involves rifting, heating and stretching of the crust as a result of lithosphere thinning over a mantle plume giving rise to a graben-like geosynclinal basin filled with continental sediments. Orogeny in these belts was the result of closure of intracontinental crust through inter-stacking of crust and delamination of subcrustal lithosphere. This type of intra-plate sedimentation and orogeny (Ensialic Orogeny) in the Proterozoic, according to Kroner, evolved into predominantly plate margin orogeny in the Phanerozoic.

The relative paucity of oceanic crustal signatures during 2.5 b.y. to 1.0 b.y. ago and apparent polar wander paths (APWP) make A. Glikson doubt whether plate tectonic processes were operative and whether the Earth had the present day surface dimensions then. He shows preference to the idea of an expanding Earth with expansion rates of 0.5 to 1.0 mm/year during early and middle Precambrian to satisfactorily account for a global sial on a smaller radius Earth and for the evolution of the Atlantic, Indian and Pacific ocean basins. His main argument is based on the lack of evidence of simatic crust occupying nearly 80% of the Earth's surface during Archaean and its transformation into sial. He suggests further investigation by palaeomagnetic and isotopic studies of the world-wide system of the 2.4 b.y. basic dykes which could provide a definitive time/place/reference grid.

Magmatism and metamorphism

The geochemical characteristics of the Early Proterozoic sediments have been reviewed by S. R. Taylor and S. M. MacLenan. They reiterate what they have stated earlier elsewhere, that the Archaean crust was dominated by basaltic and Na-rich rocks. They show a major episodic break in the REE patterns of Proterozoic and later sediments at the Archaean-Proterozoic boundary. Proterozoic crust is more evolved dominated by granodiorites with negative Eu anomalies which is the result of intracrustal melting, during which Eu was retained in the plagioclase-rich lower crust. The important point made out by the authors is that the Eu enrichment or depletion in the Earth is a crustal or shallow mantle process and is intracrustal in origin. The paper also furnishes valuable information on elemental abundances for carbonaceous chondrites, the primitive Earth mantle, present Earth continental

crust, present upper and lower continental crust and the Archaean upper crust, thus providing basic data relevant to the problem of crustal evolution.

The late to middle Proterozoic is characterized in many parts of the world by anorogenic magmatic activity in the shape of gabbroic and anorthositic rocks, charnockites and rapakivi granites and represent a unique stage of crustal development. A review of this Proterozoic plutonism in North America is presented by J. L. Anderson. The generation of crustal-derived magma under anorogenic conditions marks a major change in source material and is ascribed to thermal doming in the mantle with the mantle-derived anorthositic magmas generating the necessary heat of fusion at lower crustal levels. They are shown to possess numerous compositional traits setting them apart from the older orogenic terrains, which they commonly intrude.

Metamorphism and thermal gradients in the Proterozoic continental crust is the theme of the review paper by R. St. J. Lambert. R. C. Newton and E. C. Hansen discuss the origin of Proterozoic and late Archaean charnockites formed at high temperatures (700–900°C) and high pressures (8 ± 2 kbar) in a thick continental crust. Major hypothesis leading to charnockite formation are reviewed. This paper is of particular interest to us because examples are mainly drawn from south India. Charnockite transformation of grey gneisses (at Kabbal) is shown to be virtually isochemical ruling out the possibility of partial melting. A profoundly metasomatic origin with prior introduction of K_2O as at Madras (Pallavaram) is advocated K-metasomatism is shown to have commonly attended charnockite metamorphism, due to driving of H_2O-rich fluids ahead of a wave of hot CO_2. The authors concede that some orthopyroxene in Fe-rich charnockites may have a primary magmatic source but feel that the amount of such uniquely magmatic charnockite is probably very small. Liberation of CO_2 and high pressures could be the result of continent collision of a 15-30 km thick continent with another continental segment having carbonate shelf sediments and evaporites. They make the point that granulite terrains invariably contain abundant interlayered rocks of supracrustal origin, such as marbles, quartzites, K-rich pelites and para amphibolites and emphasize that charnockites originated by metamorphism of feldspathic crustal rocks of plutonic, volcanic sedimentary origin, in the presence of high temperature, low P_{H_2O} volatiles probably dominantly CO_2. Since the paper admirably summarises most problems relating to charnockite genesis, it should prove of great interest to all those interested in the study of the *Charnockite Problem*.

Mineral deposits

The third set of review papers include studies of mineral deposits and metallogeny in the Proterozoic. F. J. Sawkins demonstrates that Proterozoic metallogeny is dominated by deposits formed in tectonic environments characterized by rifting. A summary description of volcanic hosted and sediment hosted massive sulphide deposits, stratiform copper deposits, carbonate hosted Pb-Zn (+ Cu) deposits, mafic and ultramafic hosted copper nickel deposits is presented, drawing examples from all over the world. G. H. Gale, who examines exhalative stratabound massive sulphide deposits projects a genetic model which involves generation of magmatic fluids during the crystallization of a magma and mixing of this fluid with connate water/sea water in the upper portion of the volcanic pile. Major stratiform lead-zinc deposits of Proterozoic are examined by I. B. Lambert who points to the localization of such deposits to distinctive chemo-clastic facies deposition in basins of restricted extent. Base

metals are considered to be of crustal derivation supplied either by ascending basinal brines or by hydrothermal fluids migrating from distant centres of igneous activity. Genetic models of Proterozoic iron formations are examined by M. M. Kimberley. He feels more discussion is needed on constraints rather than models. The consistent increase in the relative abundance of chert-poor iron formation from the Archaean to Tertiary is emphasized. F. F. Langford examines the Proterozoic uranium deposits which form some of the largest depositories of uranium. All three types of deposits, sandstone, vein and unconformity type, were formed in conjunction with fluvial sandstones. Prior to 2000 m.y. oxygen-poor atmosphere enabled thorium-bearing uraninite to be weathered, transported and deposited as detrital mineral. Increase in oxygen content during subsequent periods oxidized and dissolved the uranium during weathering, separating it from the thorium which remained behind as a residue. Uranium carried in solution was deposited in reducing zones within fluviatile environments.

A conspicuous and regrettable feature of these otherwise excellent summaries is the total absence of reference to some at least of the significant metalliferous deposits of India. This is perhaps to be ascribed to lack of personal acquaintance and to the absence of descriptive accounts of these occurrences in literature.

Life

No seminar in the west is without a contribution from that versatile veteran – Preston Cloud. In this volume he presents yet another review on Proterozoic biology and handles his subject with masterly elegance. He shows that Earth was essentially completed during the Proterozoic. Continents and oceans had attained present dimensions and chemistries. Oxygen releasing photosynthesis had come to be established. Life had differentiated. Eukaryotes had got established leading to evolution of Metazoa at the Proterozoic-Phanerozoic transition. All these events are shown to be closely related to growth in oxygen content from near zero prior to 2.3 b.y. to 1% around 2 b.y., to 10% round 550 m.y. and present atmosphere levels beginning 400 m.y. ago. He emphasizes the stratigraphic utility of stromatolites and the need for a great deal more sedimentological work and geological mapping in addition to a continuous flow of good radiometric dates.

Pointed attention is drawn to potential palaeoenvironmental value of Proterozoic plankton assemblages by Vidal and Knoll. They emphasize biostratigraphic importance of the study of columnar stromatolites and acritarchs (organic-walled microfossils of problematic biological affinities).

Glaciation

The last section of the volume deals with the Proterozoic glacial record. W. B. Harland shows that the reconstruction of glacial history is dependent on the recognition of ancient glacigenic sediments. Many alleged tillites require to be examined with detailed knowledge for such an assessment. Brief summaries are presented of the Witwatersrand glacial period, Huronian glacial period, Mid-Proterozoic interglacial and late Proterozoic glacial era. The solitary reference made to India is to a tillite described by S. M. Mathur as forming the top unit of the Bijawar Group resting unconformably on the Bundelkhand granite at 2.6 b.y.

The indirect result of continental glaciation according to J. C. Crowell include, strong and rapid changes in sea level. He emphasizes the need for instituting comparison and correlation of transgressions and regressions in the Proterozoic record

with known glacial sequences. He further points to the benefits derived by utilizing techniques of seismic stratigraphy in analyzing relation between sea-level, sedimentary facies and shore line position. Such studies leading to the construction of sea-level curve for the Phanerozoic, he feels, should be extended to the Proterozoic. Transgressions and regressions should be followed from place to place aided by magnetostratigraphic methods. Study of ice ages should help in understanding other fundamental aspects of Earth History.

We make no apology for such an extended review of these volumes. As stated earlier, Proterozoic stands midway between Archaean and the Phanerozoic and a study of events in this transition has great significance in understanding Earth History. We in India have somewhat neglected the study of our Proterozoic basins on modern lines. There is virtually no geochronological or geochemical data. Sedimentological and palaeobiological studies too have not made much headway. The perusal of these most interesting and eminently readable volumes on Proterozoic geology should help focus the attention of our scientists on many problems of the Indian Proterozoic awaiting solution. There should be a more concerted effort at carrying out detailed studies and projecting the image of India on the outside world so that it can figure largely in global comparisons. The Earth is truly one world geologically. Any global review of problems will be incomplete if any one country gets neglected. We have to specifically point out to those attempting at such reviews to keep abreast of relevant knowledge by cooperating and exchanging ideas with scientists from other continents also. Appreciation of the world as a global system can be achieved only through such cooperation.

A close study of these volumes on 'Proterozoic Geology' is a must for every student of Indian geology. This is one effective way, to use the graphic words of Preston Cloud of 'recharging our intellectual batteries'. On almost all aspects covered in this volume, India can provide excellent examples. But the effort, the urge, to study and communicate in an effective way, is absent. Sedimentological and palaeobiological studies have been sadly neglected. Our interest in these fields should be revived not merely for their scientific value but for the distinct possibility of coming across important economic mineral accumulations.

Most of the good work carried by young geoscientists in India and the excellent detailed maps produced by them lie burried in cyclostyled reports which nobody reads. These require to be properly edited and processed. Unless there is a major reorientation in the publication policies of the major Earth Science Institutions in the country, the image of India will continue to suffer and remain under a cloud of neglect by the outside world. The present reviewer entertains the hope that researches carried out in the coming decade will enable bringing out similar volumes as those under review, covering all aspects of the Great Proterozoic Basins of India. Our scientists should address themselves to this task from now on.

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