Book Reviews

Metallogeny and Plate Tectonics

Edited by D. F. Strong
The Geological Association of Canada, Special Paper Number 14, 660 p., 1976.
$18.00 GAC members, $24.00 non-members

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The papers comprising this volume were presented at a special symposium held in conjunction with the joint annual GAC - MAC meeting in St. John's in May of 1974. The symposium was held in cooperation with a NATO Advanced Studies Institute including a post-symposium field trip devoted to examination of Newfoundland mineral deposits. The publication consists of 26 papers, six abstracts and a brief introduction by the editor.

It is no surprise that the plate tectonics hypothesis, whose tenants have profoundly influenced so much of the earth sciences, should strongly affect thinking in the field of metallogeny. Indeed, the recent research literature of mineral deposits shows much evidence of the impact of the new global plate tectonics. One of the important contributions of *Metallogeny and Plate Tectonics* is that it focuses for the first time the considered opinion of the geological community on the utility of plate tectonics as a conceptual framework within which the ever-growing mass of observational metallogenic data can be rationalized and put to productive use. The publication itself presents much new data on mineral deposits representing wide geographic coverage, much of it with careful reference to tectonic setting.

The subject material is grouped in five topic areas including convergent plate margins (5 papers), accreting plate margins (4 papers), intraplate deposits (5 papers), orogenic belts (6 papers) and Precambrian metallogeny (6 papers). The section on convergent plate margins deals largely with phenomena associated with very young or currently active orogens. It consists of a persuasive group of papers dealing mainly with the metallogeny of the Central Andes and Japan, and demonstrates the full potential of the plate tectonics hypothesis as a predictive metallogenic tool. It constitutes a compelling argument for careful analysis of older metallogenic belts from the viewpoint of plate tectonics. The first paper (Mitchell) shows that subduction-related magmas of modern orogens are characterized by distinctive compositions related to tectonic setting and are often associated with characteristic mineral deposits. In older orogens analogous tectonic setting - magma type - mineralization characteristics are also recognizable, and as such provide an important exploration guide. Two papers on the Central Andes (Clark *et al.* and Sillitoe) recognize the post-Paleozoic Andean orogen as a model for metallogeny at a consuming plate margin. Both are impressive illustrations of the detail in which systematic time-space aspects of magmatic-metallogenic events can be recognized and both argue persuasively for the generation of magmatic-hydrothermal systems in response to melting of subducted oceanic lithosphere along a Benioff zone. Interestingly, the two papers also provide the reader with some impression of the degree of consensus arising from a plate tectonic interpretation of a specific metallogenic province. Thus, agreement is not reached on the relationship of the Bolivian tin belt to plate consumption processes and the relationship of inferred transverse discontinuities in the subducted plate to changing patterns of mineralization is problematic. Two papers presenting detailed discussion of Late Cenozoic vulcanism and its relation to metallogeny in the Japanese arc (Sato; Horikoshi) also demonstrate the very precise reconstruction of metal-depositing events possible when relatively recent plate motions are involved. Excellent descriptions of Kuroko and other types of mineralization are presented and note is made of the remarkably restricted distribution of Kuroko-type ores in time and space. The tectonic setting of Miocene mineral deposits in Japan is regarded as genetically related to front-type volcanism at a plate margin with a descending oceanic plate.

Turning to accreting plate margins in the second section of the book discussion centres on the metalliferous sediments of the Red Sea and ophiolites, particularly the Troodos Complex. The paper on the Red Sea brine precipitates (Bignell *et al.*) is largely descriptive and presents new lithological and chemical analyses of cores from the median valley of the Red Sea. A contribution on the massive sulfide ores of Cyprus (Constantinou) is concerned with demonstrating that the conglomerate structure, porosity and colloform texture of these ores is a secondary rather than a primary feature. There can be little question that the frequent reference to these two areas as type examples of mineralization in a spreading ridge environment demands that our knowledge of metallogenic processes be as complete as possible.

Significantly, a paper discussing metallogenic contrasts in plutonic and volcanic members of ophiolites (Thayer) raises questions concerning the reality of petrogenetic links between important components of the ophiolite suite. Finally, a classification of massive sulfide deposits based on inferred geotectonic setting is presented (Sawkins). Four classes including Kuroko, Cyprus, Besshi and Sullivan-types, are recognized. The advantages of a geotectonic basis for mineral deposit classification are briefly discussed.

The section dealing with intraplate deposits presents interesting new insights into the interpretation of this class of deposits, and at the same time demonstrates many of the difficulties involved. A paper discussing lead deposits and interpretation of their depositional environments in the light of global tectonics uses data on 270 lead-bearing deposits (Laznicka). A good case is made for a comprehensive approach of this nature relying on a very large data base, but the inherent problems of highly variable data reliability are significant, as noted by the author. In a contribution on mineralization belts associated wih continental margins (Gabelman), zoned belts of orogenic and taphrogenic character are recognized. The paper draws generalizations from large numbers of deposits. This is a valuable and time-honoured approach but one in which the risk of over-generalization is always present. Thus, a statement that, "Most of the metal deposits in mineralization belts are epigenetic and are generally thought to have been derived from magmatic hydrothermal emanations, . . ." although somewhat qualified by subsequent discussion, is a rather broad assessment of genesis. The hypothesis of a St. Lawrence rift system (Kumarapeli) is developed in terms of extentional plate margin tectonics involving both Precambrian and mid-Mesozoic activity, and is associated in time and space with niobium mineralization. It is of interest to note that the author considers it necessary to justify the existence of a St. Lawrence rift system before development of a model to explain the inferred rifting. A discussion of the relationship of dykes and fault systems in the Luangwa Valley of northeastern Zambia to rifting and orogenic trends (Mossman) represents a competent structural analysis, but is only tenuously related to metallogeny. The final paper in this group (Russell) considers base metal mineral deposits of the Irish-type noting the spatial relationship of deposits in Nova Scotia, the UK and Greenland in terms of pre-drift North Atlantic continental margins and Caledonian-Appalachian geosynclinal rocks. Deposits in Ireland occur along lineaments suggestive of spatial control by vertical zones of weakness, possibly generated in response to incipient plate separation in the northern Atlantic region. The paper is a good example of the perception of order in the time-space relationships of mineral deposits arising from plate tectonic models, but not apparent in other conceptual frameworks.

The group of six papers dealing with orogenic belts represents broad geographic coverage including the Appalachians and Cordillera of North America, the Alpine-Mediterranean area, southern Scandinavia and east Australia. They are, in part, addressed to a theme of vital significance: is the plate tectonic hypothesis of predictive value in metallogeny when applied to older orogenic systems? The first paper (Petrasheck) on the geologically complex circum-Mediterranean ore belt asserts that plate tectonics provides a superior understanding of metal distribution than the concept of regional differences in geochemical properties of the crust. Nevertheless, uncertainties related to arrangement and movement of plates, age of ophiolites and the time of ore deposition preclude a definitive analysis of metallogeny. A paper on metallogeny of the Canadian Cordillera and its relation to plate tectonics (Wolfhard and Ney) illustrates some of the interpretative problems involved in metallogenic systems of long duration The relationship of various ore deposits and associated lithologies ranging in age from Helikian to mid-Tertiary, to plate tectonics is regarded by the authors as rather variable. Some of the systematic relationships of metal deposits to Benioff zones seen in the Andes are not as apparent in the Canadian Cordillera. A second contribution on the Canadian Cordillera (Stacey) reviews geological history since the Proterozoic in terms of plate theory with emphasis on the deep structure of some Triassic and early Cenozoic porphyry ore deposits. The author concludes that there is no clear understanding of the relationship between metallogeny and plate tectonics at present. A discussion of three metallogenic provinces in southern Scandinavia ranging from Eocambrian to Permian in age (Vokes and Gale) contends that interpretation in terms of global tectonics is feasible. Evidence is presented that three different aspects of continental drift are involved including both accreting and consuming plate margin phenomena as well as initial plate break-up processes. The paper presents considerable detail on the massive sulfide deposits of the Scandinavian Caledonides which should be of interest to North American geologists and illustrates the great importance of detailed compositional knowledge of associated volcanic rocks in plate tectonic reconstructions. A comparison of metallogenic patterns in three Paleozoic orogens (Swinden and Strong) emphasizes the effects of overall duration of the system on applicability of plate tectonic interpretation. In a relatively short-lived orogen such as the Appalachian, mineralization patterns of clear similarity to those of active orogenic zones are apparent. However, in longer-lived and more complex orogens, as represented by the North American Cordillera and the Paleozoics of eastern Australia, patterns are obscured and it is the latter tectonic events which are most readily explained by plate tectonics. The paper recognizes various processes which tend to obscure trends recognized in active systems and shows how these processes must be taken into account when considering older and more complex orogens. The final paper in this group presents a detailed analysis of deformation of the Tetagouche Group, host rocks of the polymetallic massive sulfides of northern New Brunswick, and a discussion of the age of deformation in relation to major tectonic events. The paper emphasizes the importance of proper assignment of various stages of polyphase deformation to orogenic events when large scale tectonic reconstruction is attempted.

The last group of papers addresses a most significant, and from the viewpoint of metallogeny, most important aspect of global tectonics: to what extent are plate tectonics applicable to Precambrian ore deposits? A comprehensive evaluation of Archean to early Proterozoic shield elements and their relevance to plate tectonics (Glikson) finds that small-scale plate tectonics are more consistent with available evidence than models based on modern, large-scale plate motions. The paper does not discuss Precambrian metallogeny as such, but is highly significant in the cogency of its arguments that an uniformitarian projection of modern plate tectonics to the Precambrian is unsupported by existing evidence. A second paper entitled Eras, Mobile Belts, and Metallogeny (Walker) is devoted to the hypothesis that worldwide patterns of mobile belt development occurred in 10 eras from 4.0 b.y. ago to the present. Most of the paper is a compilaton of data on mobile belts including lithologies, radiometric ages and some description of mineralization, considered to provide substantiating evidence for the 10 eras. The question of Precambrian plate tectonics is not seriously considered in the paper. A useful example of inferring orogenic regime from distinctive metallogeny is provided by a paper on the siver-nickel cobalt arsenide association (Badham). Examples from the European Hercynides suggest that this distinctive metallogeny develops in conjunction with a continental margin orogen above a slow-moving, shallow-dipping subduction zone. The presence of Ag-Ni, Co arsenide mineralization in rocks of the 1800 m.y. old Wopmay orogen, specifically the Great Bear batholith, N.W.T. and consideration of regional tectonics is considered to suggest Proterozoic plate subduction. A second example of Proterozoic metallogeny for which a plate tectonic model is regarded as applicable is a diverse mineralogy including ophiolite mineralization, porphyry-type Cu-Mo and Kuroko-type massive sulfides in the Red Sea region (Garson and Shalaby). A third example is the Proterozoic of southern Norway where the distribution of metal provinces and various lithologies is considered to bear much similarity with the Canadian Cordilleran orogen. The author (Torske) concludes that plate tectonics can be successfully applied to this Proterozoic orogen. Finally, the Archean Ni-sulfide mineralization associated with the magnesian lavas of Munro Township, Ontario is not easily related to plate tectonic processes, although an island-arc succession is the best modern tectonic analogue (Arndt). It is quite possible that unusual physical and tectonic conditions, at least in relation to our understanding of modern tectonics, must be considered to understand Archean metallogeny more fully. This section leaves a distinct impression that Proterozoic metallogeny may be usefully analysed within a plate tectonic framework drawing heavily on modern orogens, but that a simple uniformitarian extrapolation of modern tectonics to the Archean is beset with subtle pitfalls.

Metallogeny and Plate Tectonics provides a timely and needed overview of the impact of the new global tectonics on the mineral deposits field. The overall quality of papers is good, although there is a certain unevenness with respect to relevance to the main theme. The hallmark of the book, however, is that it contains several unusually perceptive, absolutely first-rate contributions. The organization of a rather diverse spectrum of material has been skillfully handled by the editor. Clerical errors are minimal. In general, figures, maps and diagrams are adequate although occasionally reading of legend and numerical data on maps is difficult. The book certainly deserves a place in the library of any serious student of mineral deposits, whether one's interests lean toward mineral genesis or whether one's responsibilities lie in the area of mineral exploration. Indeed, it is perhaps in the latter area, at least in the broader aspects of mineral exploration and prospecting, where spin-off from the new global plate tectonics may be most dramatic.

MS received December 6, 1976

Scenic Wonders of Canada—An Illustrated Guide to our Natural Splendors

Readers Digest Association (Canada) Ltd, in conjuction with the Canadian Automobile Association, 384 p., 1976. $24.95

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Canadians who appreciate nature are fortunate. Our land offers something for almost everyone - the gently rolling terrain of Prince Edward Island, the rugged majesty of the Rockies, the temperate climate and subdued landscape of southern Ontario or the lonely beauty of Ellesmere Island. It may seem to many that our natural beauty, being so abundant, needs only to be enjoyed. Fortunately in more densely populated countries and indeed in some parts of our own land it long ago became obvious to a concerned few that enjoyment implied responsibility and certain lands were set aside. Banff, started in 1885, was the first of a variety of national parks. National parks cover 50,000 square miles, provincial parks 110,000 square miles, two thirds of the latter area being in Quebec with its extensive wilderness areas. In addition there are many hundreds of historic sites, conservation areas and other features that mark and preserve our heritage. The national parks, few in number but large in size, are for the most part wilderness areas whereas the provincial parks, in addition to large expanses such as Algonquin Park, include many hundreds of small areas devoted to specific scenic features. Some may wish that our parks were more numerous and more restrictive, others may feel that more varied uses should be permitted but at least we have a foundation on which to build.

Many of our parks were created to preserve outstanding natural features whether geological such as the badlands of Alberta or ecological such