The Non-relation Between Metal Provinces and Theories of Plate Tectonics in the Western United States

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Zusammenfassung

„Über das Fehlen einer Beziehung zwischen Erzprovinzen und der Theorie der Plattentektonik in den westlichen Vereinigten Staaten“

In einer früheren Abhandlung (*Noble*, 1970) wurde der Schluß gezogen, daß die Anordnung und Verteilung der Erzprovinzen in den westlichen Vereinigten Staaten das Ergebnis einer ursprünglichen, vor-krustalen Heterogentität im Oberen Mantel sei, und daß die Metalle dieser Lagerstätten aus dem Oberen Mantel herzuleiten seien. Die enge räumliche und zeitliche Verknüpfung zwischen den meisten Erzlagerstätten und einigen Intrusivgesteinen wurde strukturell bedingt gedeutet: der Aufstieg von Magma aus dem Oberen Mantel ließ druckentlastende Kanäle entstehen, die den Aufstieg von Metallen und anderen erzbildenden Bestandteilen erleichterten.

Eine wachsende Zahl von Altersdatierungen aus den westlichen Vereinigten Staaten erlauben es nun, die Altersverteilung der extrusiven und intrusiven Gesteine sowie der Erzlagerstätten in Karten zusammenzuzeichnen. Diese Altersverteilungen zeigen im allgemeinen konzentrische Anordnung, wobei die älteren Einheiten außen, die jüngeren im Zentrum liegen. Die Art der Anordnung scheint wegen der großen Menge an abgesetzten Metallen, wegen dem Alter der Lagerstätten und der sehr großen Verbreitung der Erzprovinzen mit keinem Modell der Plattentektonik vereinbar zu sein. Es wird daher der Schluß gezogen, daß die Erzlagerstätten der westlichen Vereinigten Staaten durch die „new global tectonics“ nicht berührt wurden.

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Abstract

In a previous paper *(Noble,* 1970), it was concluded that the patterns of distribution of metal provinces in the western United States were a result of a primitive or precrustal heterogeneity in the upper mantle, and that the metals of the ore deposits making up these patterns were derived from the upper mantle. The close space and time association between most ore deposits and some intrusive rocks was believed to be structural: the ascent of magma from the upper mantle provided avenues of released pressure that facilitated the rise of metals and other ore-forming constituents.

Models derived from theories of plate tectonics have been developed to explain tectonism, the development of extrusive and intrusive rocks, and the formation of ore deposits *(Coats,* 1962; *Hamilton,* 1969; *Dewey & Bird,* 1970; *Dietz,* 1970; *James,* 1971; *Sillitoe,* 1972a, b; *Clark & Zentilli,* 1972). In particular, subduction zones developed by the collision of oceanic and continental plates have been postulated, but ascent of molten material from the mantle at the boundaries between moving plates has also been suggested. I will discuss the space and time relationships between extrusion, intrusion, and ore formation in the western United States in terms of possible subduction zones.

The extrusive rocks can be divided into three age groups, Laramide, mid-Tertiary, and Pliocene-Pleistocene. The Laramide pattern forms a U-shape, continuing NNW into Canada, with a maximum spread of 800 mi (1280 km). The mid-Tertiary rocks occupy a large area mostly inside the Laramide area. The Pliocene-Pleistocene rocks, predominantly basalts and andesites, form one belt of andesite near the coast and two transverse belts of basalt, all overlapping the earlier rocks. The subduction hypothesis would require two subduction zones in opposite directions, dipping inward, a most unlikely situation. The distribution of the Pliocene-Pleistocene rocks might mark boundaries between moving plates, an ad hoc assumption at present.

The intrusive rocks have not been adequately dated, and their pattern can be discussed only in general terms. Large Mesozoic batholiths predominate near the coast and extend in places as much as 500 mi (800 km) eastward. Smaller Laramide batholiths and plutons are very extensive. For the most part they lie to the east of the Mesozoic batholiths, to a maximum distance of 1200 mi (1900 km) from the coast. The two age groups overlap somewhat along a central belt; more dating is needed here. Mid-Tertiary intrusive rocks are less extensive (inadequate dating?). The principal occurrence overlaps the boundaries between the older groups, but there is one linear belt near the coast. The space-time relationships between Mesozoic and Laramide groups would satisfy a subduction model only with a dip of a few degrees, and the mid-Tertiary group would not be explained.

The pattern of distribution of the ore deposits is more complex than those of the intrusive and extrusive rocks, in part because a greater proportion of the ore deposits has been dated by isotopic techniques. Mesozoic ore deposits form an

arcuate belt parallel to the coast, mostly within 200 mi (320 km) of the coast but in places extending to 450 mi (720 km) inland. Laramide ore deposits, the most important in terms of total value, also form an arc, but this time facing away from the coast to a maximum distance of 1000 mi (1600 km). They continue into Canada but for only a short distance into Mexico. Tertiary deposits are somewhat less extensive but quite important commercially. They occupy the gap between the Mesozoic and Laramide arcs and also overlap the Laramide areas. Datings presently available permit separating late Tertiary from mid-Tertiary, but the areas of occurrence are similar, and additional sampling may close this gap. If we attempt to relate the pattern of ore deposition to a hypothesis of subduction, once again, as for the extrusive rocks, we need two opposite facing subduction zones.

Conclusion

These studies do not contradict the general conclusions of the hypotheses of continental drift, sea-floor spreading, and plate tectonics, but they indicate to me that probably the processes of extrusion and intrusion and certainly the process of ore formation in the western United States have no relation to those hypotheses and were not governed by them. The initiation of sea-floor spreading in the Atlantic Ocean and the first great surge of batholithic intrusion in western United States, both in early Mesozoic time, were nearly synchronous and may have been related, but the nature of the relationship is not clear. Some metallization accompanied this orogeny, but unless very large amounts have been completely destroyed by erosion, which seems unlikely, the succeeding Laramide orogeny and volcanism produced much greater amounts of metallization, without any clear time relationship to global tectonics. The simultaneous concentration and separation of metals, on an arcuate zone reaching to distances of about 1000 mi (1600 km) from the continental margin, cannot be fitted into any global tectonic model known to me. Large forces, or large amounts of heat, are required to explain the volcanism and metal formation in the western United States, and it seems likely that these were contained within the areas I have described; we need to look down, not to one side, for the sources *(Gilluly,* 1970). It has been noted *(Damon & Mauger,* 1966; *Armstrong,* 1970) that volcanism on both large and small scale tends to begin with a great surge and then taper off gradually. It has also been noted here that volcanism shows some tendency to contract toward a center; in a broad way, older units surround younger units in the age distribution maps. These two generalizations seem to point to the sporadic and rather sudden generation at great depths of large amounts of heat by mechanisms for which at present we probably have no adequate explanations. The rise and emplacement of the metals to form ore deposits is probably part of this process, and these likewise are not yet explained.

References

Armstrong, R. L. (1970): Geochronology of Tertiary igneous rocks, eastern Nevada and vicinity, USA. — Geochim. Cosmochim. Acta, *34*, p. 203—232.

Clark, A. H. & *Zentilli*, M. (1972): The evolution of a metallogenic province at a consuming plate margin: The Andes between latitudes 26° and 29° South. — Canadian Min. Met. Bull., *65*, p. 37 (abstr.).

Coats, R. R. (1962): Magma types and crustal structure in the Aleutian Arc. In *Macdonald*, G. A. & *Kuna*, H., Editors: The crust of the Pacific Basin: Amer. Geophys. Union Geophys. Mon. *6*, p. 92—109.

Damon, P. E. & *Mauger*, R. L. (1966): Epeirogeny-orogeny viewed from the Basin and Range Province. — Amer. Inst. Min. Eng. Trans., *235*, p. 99—111.

Dewey, J. F. & *Bird*, J. M. (1970): Mountain belts and the new global tectonics. — Jour. Geophys. Res., *75*, p. 2625—2647.

Dietz, R. S. (1970): Continents and ocean basins. — In *Johnson*, H. & *Smith*, B. L., Editors: The megatectonics of continents and oceans: New Brunswick, N. J., Rutgers Univ. Press, p. 24—46.

Gilluly, J. (1970): Crustal deformation in the western United States. — In *Johnson*, H. & *Smith*, B. L., Editors: The megatectonics of continents and oceans: New Brunswick, N. J., Rutgers Univ. Press, p. 47—73.

Hamilton, W. (1969): Mesozoic California and the underflow of Pacific mantle. — Geol. Soc. Amer. Bull., *80*, p. 2409—2430.

James, D. E. (1971): Plate tectonic model for the evolution of the central Andes. — Geol. Soc. Amer. Bull., *82*, p. 3325—3346.

Noble, J. A. (1970): Metal provinces of the western United States. — Geol. Soc. Amer. Bull., *81*, p. 1607—1624.

— (1974): Metal provinces and metal finding in the western United States. — Mineralium Deposita (in press).

Sillitoe, R. H. (1972a): A plate tectonic model for the origin of porphyry copper deposits. — Econ. Geol., *67*, p. 184—197.

— (1972b): Relation of metal provinces in western Amerika to subduction of oceanic lithosphere. — Geol. Soc. Amer. Bull., *83*, p. 813—817.

The substance of this paper was first presented at the Leoben symposium on November 6. 1972. A more extended discussion, with applications to ore finding, will appear in Mineralium Deposita (Noble, 1974).