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JHC — a w il written, research review!

W. L. K.

DEC 20 1973

AMERICAN SMELTING AND REFINING COMPANY
TUCSON ARIZONA

December 19, 1973

Memorandum to: W. L. Kurtz

From: F. T. Graybeal

Plate Tectonics Meeting

A two-day meeting in Vancouver with John Dewey and Jack Bird served as an introduction to the general concepts of plate tectonics and their application to the understanding of the evolution of mountain belts. Most of what they discussed can be derived from the literature which has been nicely collected in the book Plate Tectonics, published by the A. G. U., and which is in our library.

The applications of plate tectonic theory to ore finding were considered by most (all?) ASARCO personnel to be rather vague. It would appear that the best applications are in possibly delineating new metallogenetic provinces and perhaps as a guide to selecting areas for regional prospecting in the Southwest Pacific.

With respect to metallogenetic provinces, Bird feels that most porphyry copper provinces may be the result of subduction and melting of a Red Sea-like metalliferous sediment, a view expressed by others in the literature. Bird suggests we assume that such sedimentary deposits may be fragmented during spreading of the sea floor and that we should search for the other half or third of these deposits on the opposite side of the mid-ocean ridge. He suggests that one-third of the British Columbia porphyry copper source rocks were subducted under the Aleutian Islands and that we should look there.

With respect to prospecting in the SW Pacific, it is well known that continent-ocean crust and island arc-ocean crust collisions appear most favorable for the generation of calc-alkaline magmas and the associated porphyry copper deposits. Although this subject was not discussed, such collision zones would be the most favorable for further prospecting.

The importance of obducted ophiolites as targets for base metal exploration received little attention. A brief comment on the occurrence of chromite at specific zones in these rocks was countered by the observation that ASARCO is not particularly interested in this sort of thing.

Of scientific interest were some samples Bird had of massive metallic Ni-Fe-Cu-Ca inclusions from some ophiolites in the Klamath Mtns. The exceptionally reducing conditions required by metallic iron led Bird to suggest these are samples of the outer core, about which he plans to publish in the near future.

It was concluded that, although specific suggestions could not be made at the present time, the general concepts discussed were food for thought and that ideas for generating exploration targets could probably be forthcoming from the various offices in an unpredictable way. It is my impression that the global scale of features which relate to plate tectonics are of perhaps several orders of magnitude larger than the more district scale of features with which the modern explorationist is concerned, particularly in North America. This, complicated by the highly ambiguous plate tectonic relationships for pre-Mesozoic and, more particularly, Precambrian times indicate to my perhaps limited vision that plate tectonic theory, at its present stage of development, will have little practical use in base metal exploration in this decade. The potential scientific value of this theory in regard to the origin of ore deposits is large, although definitive studies of this nature in the literature are largely lacking. An attempt should be made by the exploration staff to keep current on this subject, perhaps through periodic seminars, because I am convinced that the experienced explorationist is better qualified to judge the value of such concepts than is the less-practical minded member of the academic community.

F. T. Graybeal

F. T. Graybeal

FTG:lb

ASARCO

ASARCO (AUSTRALIA) PTY. LTD.
190 HAY STREET EAST, PERTH,
WESTERN AUSTRALIA 6000
TELEPHONE: PERTH 25 9533
CABLES: "ASARCO PERTH"

RECEIVED
OCT 26 1976
EXPLORATION DEPT.

PLEASE ADDRESS MAIL TO:
ASARCO (AUSTRALIA) PTY. LTD.
P.O. BOX 6010
HAY STREET EAST, PERTH 6000
WESTERN AUSTRALIA

October 20, 1976.

Mr. J.H. Courtright
Chief Geologist
ASARCO Incorporated
Tuscon Office

Ore Genesis

Dear Harold,

In the event you do not receive Mineral Science and Engineering, herewith is a paper from the April 1976 issue which is a general overview of the spacial relation of some metallic deposits to tectonic settings. This article with its extensive bibliography is a good summary of factors influencing the distribution of some classes of ore bodies in orogenic belts.

Yours sincerely,

D.M. Fletcher

Encl.

cc TCOsborne with enclosure.

J. H. COURTRIGHT

from UCSB Research Review, 1983
A31

Back file Plate Tectonics

sible: The source and character of marine magnetic anomalies. J. Geophys. Res. 88, No. B4, pp. 3403-3418.

Parker, R. L. and Huestis, S. P. (1974): The inversion of magnetic anomalies in the presence of topography. J. Geophys. Res. 79, pp. 1587-1593.

MAGMAGENESIS AND EMPLACEMENT HISTORY OF THE COASTAL BATHOLITH OF PERU, AND IMPLICATIONS OF LEAD ISOTOPES AND URANIUM-LEAD GEOCHRONOLOGY FOR THE MINERALIZATION AND CRUSTAL EVOLUTION IN A CONVERGENT PLATE BOUNDARY

Mukasa, Samuel B.

The continental margin of Peru has been the site of repeated igneous activity through much of the Phanerozoic. Products of this activity are manifested in three major batholiths: San Nicolás, Coastal and Cordillera Blanca, as well as in isolated stocks and various volcanics. The San Nicolás Batholith which intrudes Precambrian granulites and gneisses, is oldest and closest to the boundary between the continental and oceanic crusts. The Coastal Batholith which intrudes a Lower Jurassic eugeosynclinal sequence and its own volcanic ejecta is intermediate in both position and age, and the Cordillera Blanca Batholith which intrudes a Lower Jurassic miogeosynclinal sequence is youngest and farthest from the lithospheric boundary. The three batholiths, the sedimentary and metamorphic rocks they intrude, and the Triassic to Plio-Pleistocene volcanics in the area constitute the Western Cordillera of Peru.

My research is primarily focusing on the Lima and Arequipa Segments of the Coastal Batholith. The batholith, for which the first modern and major account was given by Cobbing and Pitcher (1972a), is Cretaceous to Neogene in age. Plutons within it exhibit an increase in acidity with time. Thus, the intrusive relationships are such that gabbros and meladiorites are cut by tonalites which in turn form the host rocks to granodiorites and monzogranites. Rocks of intermediate composition predominate over basic and acidic varieties although it should be noted that basic rocks were probably once very extensive. Notable petrogenetic studies in the batholith include those of Regan (1976) and Le Bel (1979) who postulate that magmas were exclusively derived from the mantle, and those of Cobbing, Pitcher and Taylor (1977) and McCourt (1981) who favor mixing between mantle-derived magmas and those generated in the lower crust.

The San Nicolás and Cordillera Blanca Batholiths which are being investigated on a reconnaissance basis only are much smaller than the Coastal Batholith, and are a lot less studied. The San Nicolás Batholith consists of basic to intermediate hornblende-rich plutons of not very well constrained, but probably Paleozoic age, while the Cordillera Blanca Batholith is predominantly leucogranodioritic in character and Neogene in age (Stewart et al., 1974; Wilson, 1975; and Shackleton et al., 1979).

Efforts already underway involve five principal areas. These are determination of the emplacement history of the Coastal Batholith using U-Pb geochronology; evaluation of the super-unit concept which currently implies the emplacement of a particular group of rocks more or less to-

gether within a limited time and space frame; isotopically evaluating the limits of mantle-crust interactions during magma generation; pinpointing the origin or origins of a number of copper ore deposits associated with the emplacement of various super-units in the Coastal Batholith; and integrating reconnaissance zircon U-Pb ages, and lead and oxygen isotopic data from the San Nicolás and Cordillera Blanca Batholiths with more complete data from the Coastal Batholith to formulate a general statement about the Phanerozoic crustal evolution of the Peruvian continental margin.

Preliminary lead isotopic results have shown that there appears to be a spatial association between the occurrence of an old crustal component in the Phanerozoic intrusives and the present day exposures of Precambrian basement. Away from Precambrian exposures within the plutons, it may therefore be possible to characterize the nature of the sub-Andean mantle in Peru. Finally, on the basis of zircon U-Pb ages, an emplacement history lasting only 50 million years (between 85 Ma and 35 Ma) is tentatively suggested for the Lina Segment of the Coastal Batholith.

LATE QUATERNARY SHELL BEDS, WESTERN SHELF, NEW ZEALAND

Norris, Robert M. and Grant-Taylor, T. L.

Extensive buried shell beds and shelly zones have been sampled by coring over much of the western shelf between Cape Foulwind on the south and the mouth of the Waikato River on the north. The maximum thickness of shell penetrated is about 2 meters, but the deposits may be 5 or 10 meters thick at many places, judged by very similar but slightly older deposits exposed on land near Wanganui.

Radiocarbon dates show that these shell beds were deposited during the last major marine transgression which began about 20,000 years ago and ended about 5-6000 years ago. During the transgression, but especially during the past 5-6000 years when sea level stabilized near its present position, the shell beds were gradually buried by the sandy muds and muddy sands which blanket much of the present western shelf.

Radiocarbon dates were obtained on specific molluscan genera in various states of preservation and at different levels in a single core. This detailed dating shows that the shell beds have been subjected to intermittent stirring and mixing for periods as long as 3-7000 years, during which time some shell material was added from other sources, both buried and surficial.

The late Tertiary and early Quaternary (pre-Hawera?) deposits exposed on shore near Wanganui provide a record of at least seven earlier marine transgressions and as such are believed to provide an on-shore analog of the modern shelf stratigraphy.

These on-shore equivalent shell beds suggest that the shelf shell beds may prove to be 5 or more meters thick and many kilometers long and wide. Moreover, because many of the fossil shell beds at Wanganui rest on deformed and eroded older sedimentary rocks, it is believed likely that a similar relationship will be found beneath the shelf shell beds.

The sea level curve deduced from the dated shelf shell beds demonstra-

FIGURE 5 Alluvial tin workings adjacent to granite pluton, Jos Plateau, Nigeria, in a poorly defin elongate belt of stanniferous plutons possibly related to hot spot activity. Photo: J.A. Ba

FIGURE 6 Apatite-rich eluvial soil mine in arena of Sukulu carbonatite, Ugand within intra-continental East Africa rift zone. Photo: Dr T. Dun

FIGURE 7 Pyrochlore-rich eluvial soils overlying pyrochlore-carbonatite on summit plateau of Chilwa Island within intra-continental East Africa rift zone. Photo: Dr M.S. Garson.

FIGURE 8 Sodium carbonate lavas and ashes capping the active Oldoinyo Lengai carbonatite volcano in the East Africa rift zone. Lake Natron in background is large reserves of sodium carbonate, chloride, and fluoride derived from Oldoinyo Lengai and possibly also from hydrothermal solutions. Photo: Dr T. Deans

ASARCO

Southwestern Exploration Division

WK File
Plate Tectonics

July 22, 1977

Mr. John C. Balla
Manager, NW Exploration Division
Spokane Office

Dear John:

Attached is a somewhat obscure article I dug out of my files which I believe came from EOS -- probably about 1974. It has some possibly useful comments and references on aulacogens and may possibly be of use to you in your search for another Sullivan mine. It looks like good stuff for mid-winter mega-thinking.

Very truly yours,

F. T. Graybeal

FTG:lb
Att.

cc: WLKurtz - w/att.

Epeirogeny and Plate Tectonics

H. W. Menard

WLK

the increasing use of HMPA in the Du

thermal systems known on the sea floor.

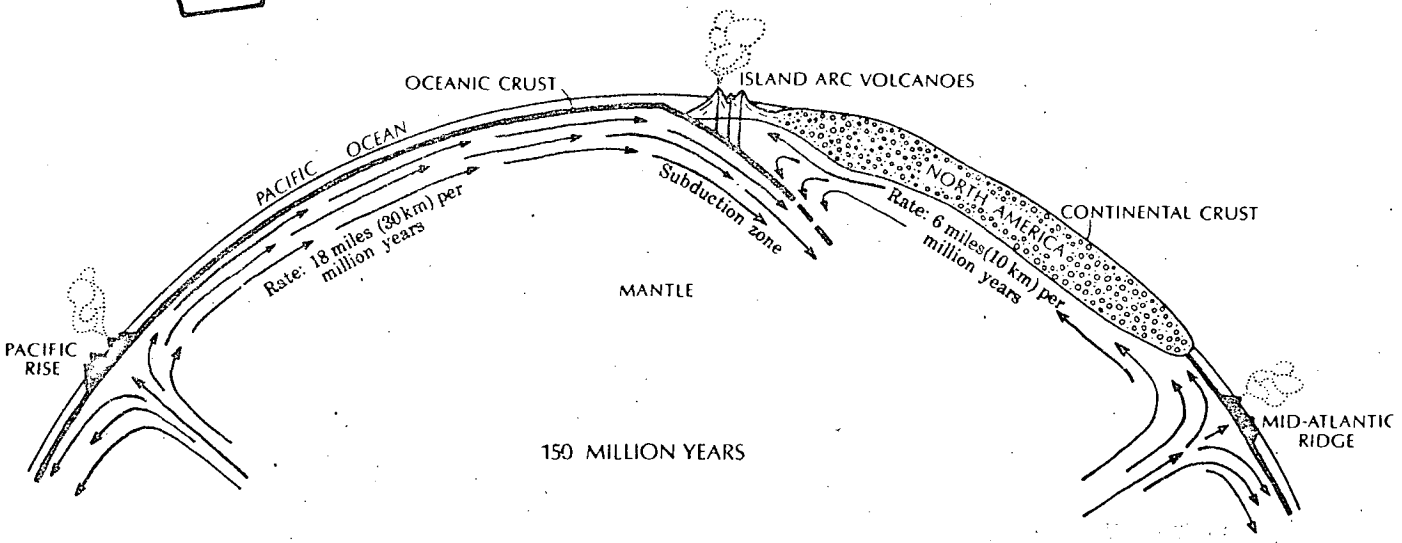
Plate Tectonics

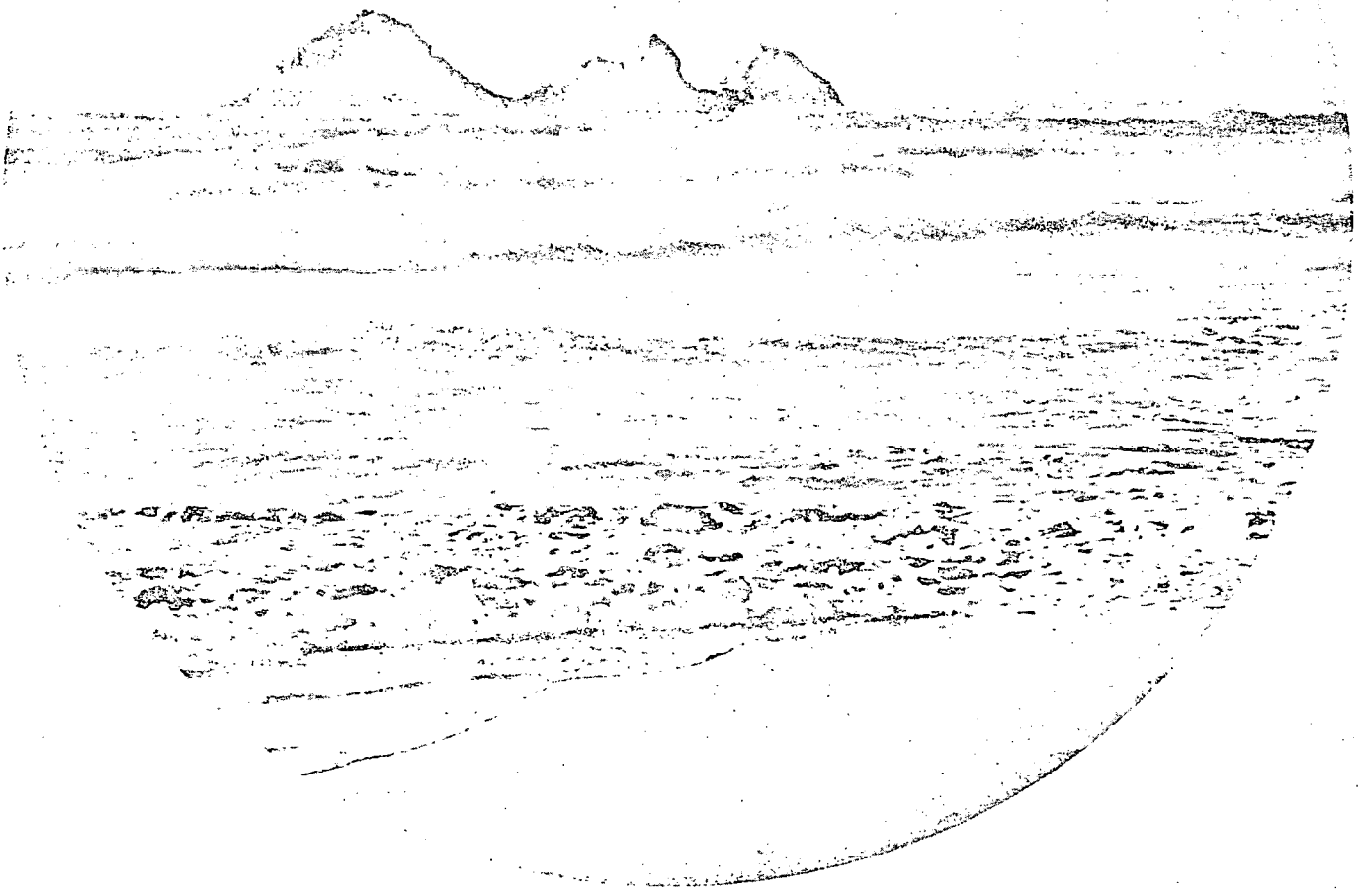
CGEOA 27(1) 1-20(1974)

Single copy 25¢

CALIFORNIA GEOLOGY

January 1974





Model for the origin of Sierran granites

Most of our readers will recognize the name, Paul C. Bateman, as that of one of the foremost authorities on the Sierra Nevada. Dr. Bateman has spent most of his working life studying the Sierra, concentrating in an area in the central Sierra Nevada that contains many varieties of granitic rocks of several ages.

In CDMG's Bulletin 190, **Geology of northern California,** *he and Professor Wahrhaftig of the University of California, Berkeley, presented a series of diagrams that formed a model for the generation of magma—and therefore granitic rocks—in the Sierra, based on available information. Since then, new ideas concerning earth history embodied in the concepts of global tectonics have caused all geologists to reexamine their ideas.*

The following drawings present Dr. Bateman's latest ideas regarding magma generation in the Sierra Nevada. Our readers might wish to compare them with his diagrams of 1966, published in **Geology of northern California** *on page 124.*

We are particularly grateful to Genny Schumacher, who has made this set of diagrams available to us. They were written especially for the forthcoming edition of **Deepest valley: guide to Owens Valley and the eastern Sierra,** *of which she is editor.*

The first edition of **Deepest valley** *had many contributors, all experts on the Owens Valley part of the Sierra Nevada. Dr. Bateman was one and has prepared this text as part of his effort in bringing the next edition up to date.*

The revised edition will be published in early summer by Wilderness Press of Berkeley. The publisher has graciously consented to allowing us to "scoop" him with this article. . . . **Editor**

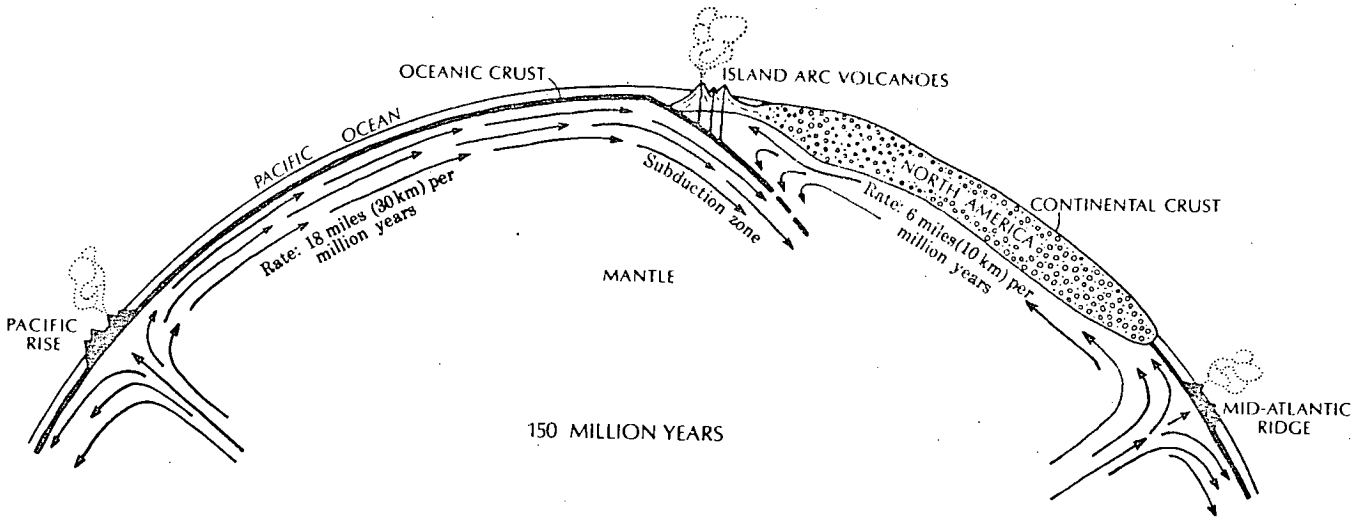
Model for the origin of Sierran granites

By Paul C. Bateman, United States Geological Survey

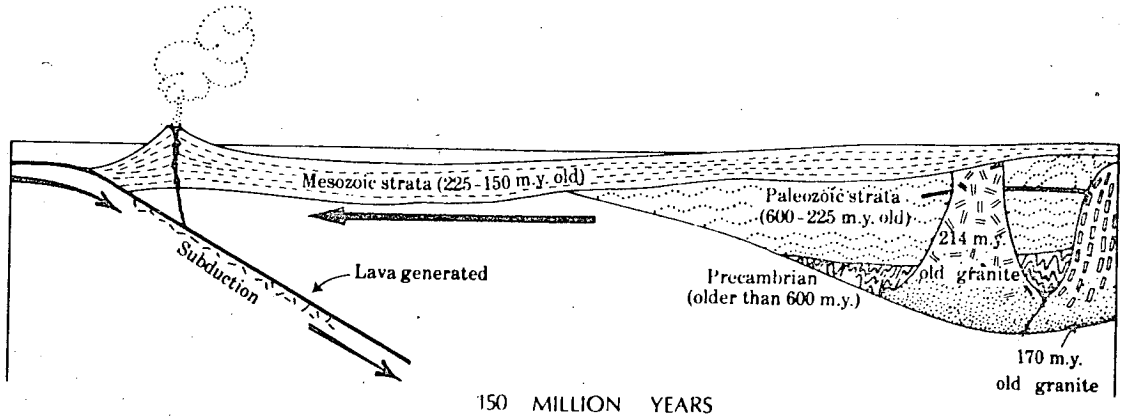
In recent years, the earth sciences have been going through the most profound and exciting conceptual revolution of this century. This revolution has been brought about by convincing documentation of an old idea—that the floors of the oceans move like conveyor belts, carrying the continents from place to place. During this same period, much new information about the granites has been obtained through study of the Sierra Nevada itself.

To take account of these new developments, a new model for the origin of the granites is presented here. This model is in the form of a series of diagrams to illustrate how the granites might have been formed. They constitute a scientific "model" in that they provide an explanation that fits the available information, but which can't be proved. Typically, a successful model is modified as new data and concepts appear; unsuccessful ones that cannot be modified to accommodate new data are abandoned. Examples of successful models are the structure of the atom and the concept of organic evolution. Doubtless, the model shown here will need to be modified again more than once, but it fits the facts now known, is in keeping with modern concepts, and may even approximate the truth!

The outer skin of the earth is called the crust; the crust of continents is much thicker and of different composition than the crust of the ocean basins. Beneath the crust and extending downward to the earth's core is the mantle, composed of darker and heavier rocks than are found in either continental or oceanic crust. According to modern concepts, plastic (viscous) flow within the mantle is the chief cause of earth movements. Material rises from great depths at ocean ridges, flows laterally, then is returned to the depths at deep ocean trenches along major shear zones along which one plate slides down and under (is subducted beneath) the other.



The diagram above shows the broad relations 150 million years ago. The Atlantic Ocean was still narrow, but was widening by plastic flowage both ways from the mid-Atlantic Ridge, carrying Europe and North America apart. At the same time spreading was also taking place in the Pacific Ocean. As a result of these movements, North America was being carried westward toward the eastward-moving part of the Pacific Ocean. Where the two oppositely moving plates met, the eastward-moving plate slid down and under the westward-moving plate along a subduction zone, generating lava that penetrated through the thin edge of the North American plate and erupted into the sea, forming a chain of island-arc volcanoes, of which the Aleutians are a present-day example.

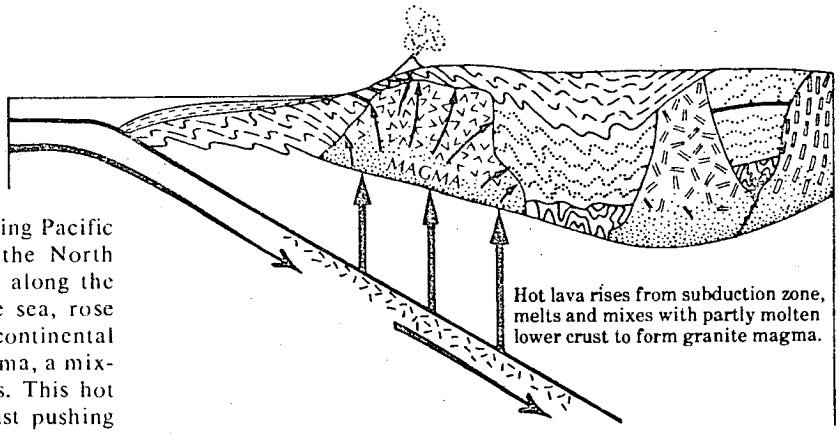


150 MILLION YEARS
DEPOSITION AND VOLCANISM

Vast quantities of volcanic debris from the volcanoes flowed as lava and fell as ash into the sea; between the continent and the island-arc volcanoes, it mixed with smaller amounts of material eroded from the continent. The granites shown in the east are older than the events to be described, but probably formed in much the same way as the younger granites.

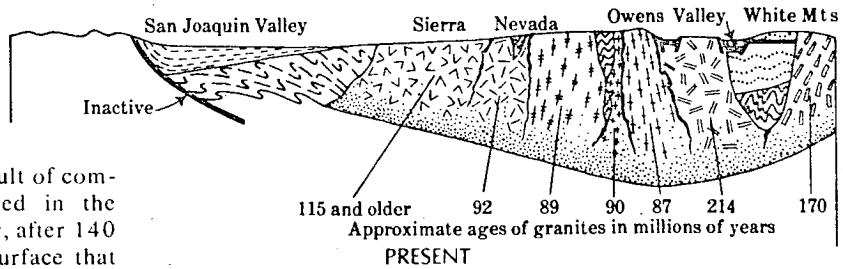
140 MILLION YEARS
NEVADAN OROGENY

Between 150 and 140 million years ago a cataclysmic event occurred. The oppositely moving plates, which earlier had been slipping quietly one under the other, and for reasons not yet understood, interacted violently. The rocks in the western edge of the continent and in the marginal sea were squeezed strongly, folded intricately, tilted westward, and piled up along eastward-dipping faults in overlapping slabs. This event is called the Nevadan orogeny.



115 MILLION YEARS
POST-NEVADAN GRANITES

Deformation ended when the eastward-moving Pacific Ocean floor once again began to slip under the North American plate. Now, however, lava generated along the subduction zone, rather than erupting into the sea, rose into the continental plate. It melted part of the continental rocks and mixed with them to form granite magma, a mixture of hot molten rock and suspended crystals. This hot magma then rose buoyantly into the upper crust pushing the solid rocks aside and upward, melting some and reacting chemically with others. Doubtless volcanoes fed by the granite magma erupted at the ground surface. The earliest granitic rocks generated after the Nevadan orogeny were in the region of the western foothills, and successively younger ones were emplaced progressively farther east. The youngest ones are along the Sierra crest.



PRESENT
TILTING, FAULTING, AND EROSION

Thickening of the continental crust as a result of compression during the Nevadan orogeny resulted in the ground surface being lifted above sea level. Now, after 140 million years of erosion, we are looking at a surface that once was deeply buried, perhaps by 5 to 10 miles of rock.

NOTE: Data from island arcs indicate the depth to the subduction zone directly beneath active volcanoes is consistently between 100 and 200 km (60 and 120 miles). Therefore, the depth to the subduction zone in the sections 150 and 115 million years ago is actually much greater than shown.

JHC → ck Math Intrans

LARAMIDE HOTSPOT, COPPER DEPOSITS AND PLATE MOTION IN ARIZONA, SONORA AND NEW MEXICO

Donald E. Livingston

Submitted to Nature
25 April 1973

Department of Geosciences
Contribution No. 79

LARAMIDE HOTSPOT, COPPER DEPOSITS AND PLATE MOTION IN ARIZONA, SONORA AND NEW MEXICO

Donald E. Livingston
Laboratory of Isotope Geochemistry
Department of Geosciences
University of Arizona
Tucson, Arizona 85721

References, Cont'd.

~~FTS~~, ~~GXS~~, ~~AG~~, ~~FDS~~ → WLK File → Plate Tectonics

see also Dewey & Bird (obtained by Abacus) being circulated!

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

W. L. K.
AUG 3 1972

August 2, 1972

TO: W. L. Kurtz

FROM: J. D. Sell

IAGOD Circular

The International Association on the Genesis of Ore Deposits (IAGOD) recently submitted a circular on their activities and plans.

Dr. Kutina's paper on "Global Tectonics and Metallogeny Project" is of interest and it was fortunate that a copy of the reference list could be secured. Certainly, as Fred Graybeal has verbally pointed out, this type of study is of great benefit in deciding what areas of relatively unknown areas such as Alaska, etc., should be entered into in the diligent search for specific mineral deposits.

The other two papers are bibliographies of recent papers in German and perhaps, as Al will be able to tell us, gives some thoughts on the direction being taken by others in the studies of ore deposits.

James D. Sell

James D. Sell

JDS:lad

I. A. G. O. D.

INTERNATIONAL ASSOCIATION ON THE GENESIS OF ORE DEPOSITS

President: C. F. Park, Jr (Stanford)
1st Vice-President: V. I. Smirnov (Moscow)
2nd Vice-President: T. Watanabe (Tokyo)
Secretary General: M. Vaněček (Prague)
Membership Secretary: P. Zuffardi (Cagliari)
Chief Treasurer: R. W. Boyle (Ottawa)

June 10, 1972

To Members of IAGOD

Re: (1) IAGOD at the 24th IGC in Montreal

(2) IVth Symposium of IAGOD in Varna, 1974

(3) Bibliography of the study of ore genesis in the GDR

(4) Newsletter of IAGC

(5) Global tectonics and metallogeny project

(1) IAGOD at the 24th International Geological Congress in Montreal

The following preliminary time-table of the IAGOD sessions at the 24th IGC in Montreal is proposed:

Aug.22, 14.00 IAGOD Council Meeting, Hotel Champlain, Huronie B

14.00 Symp.112, IAGOD-COFFI, Hotel Queen Elizabeth, Du Luth

Aug.23, 14.00 Symp.112, IAGOD-COFFI, Hotel Queen Elizabeth, Du Luth

14.00 Symp.118, IAGOD-WG Manganese, Hotel Champlain, Huronie B

Aug.24, 14.00 Symp.118, IAGOD-WG Manganese, Hotel Champlain, Huronie B

14.00 IAGOD-COFFI, Hotel Champlain, Habitation B

18.30 Reception and dinner of SEG, SGA, IAGOD, Sheraton-Mount Royal Hotel, Champlain Room

Aug.25, 14.00 IAGOD-WG Manganese, Hotel Champlain, Huronie B

14.00 IAGOD-WG Prospecting, Hotel Champlain, Huronie A

Aug.28, 14.00 IAGOD General Assembly, Hotel Champlain, Viger ABC

Aug.29, 14.00 IAGOD Council meeting, Hotel Champlain, Huronie B

For the IAGOD General Assembly session the following agenda is proposed:

1) Report of the IAGOD Secretary General
2) Report of the Membership-Secretary
3) Report of the Treasurer
4) Statement of the Finance Committee
5) Reports of the Chairman of Commissions and Working Groups
6) Presentation of and voting on amendments to the statutes
7) Presentation of By-laws
8) Election of a new IAGOD Council

The provisional chairman of the WG Genesis of Mineral Deposits as a Basis for Prospecting, Professor S. Jankovic, has announced the following programme for the WG session:

1) The constitution of the Working Group
2) "Genesis of Ore Deposits as a Basis for Prospecting" - a brief review presented by S. Jankovic
3) Discussion of relevant problems and future activity of the group

The programmes of the COFFI Symposium and of the meetings of WG Manganese will be announced in the IGC Program.

Those who wish to take part in the SEG-SGA-IAGOD dinner are requested to send 10.00 Can.doll. to:

Society of Economic Geologists
c/o Executive Suite Limited
Suite 46, 1390 Sherbrooke Street West
Montreal, 109, Quebec, Canada
Attention: Mrs. John B.A. Castle

(2) IVth Symposium of IAGOD in Varna 1974

The IVth Symposium of IAGOD will be held in Varna - Bulgaria in September, 1974. The following topics will be discussed:

a) Factors controlling the vertical extent of ore deposition
b) Base metals (Pb,Zn,Cu) mineralization associated with volcanism (including minor intrusions)

c) Significance of isotopic composition for the genetic interpretation of ore deposits.

The first circular was already dispatched and can be received upon request from the Organizing Committee of the IVth IAGOD Symposium, 36 street, block 2, Sofia 13, Bulgaria.

(3) Bibliography of the study of ore genesis in the GDR

According to the decision of the IAGOD Council which met in Kyoto on Aug.31, 1970, the National Committee of German Democratic Republic for IAGOD has prepared a bibliography reviewing the study of ore genesis in the GDR in 1967-1969, which you will find enclosed. The IAGOD Secretary appreciates very much this work of the IAGOD members from the GDR and is asking hereby the National Representatives of other countries to prepare similar reviews.

(4) Newsletter of IAGC

The International Association of Geochemistry and Cosmochemistry announced to the IAGOD Secretary its willingness to send copies of the Newsletter of IAGC to the IAGOD members who are interested. The Newsletters are distributed by Professor Earl Ingerson, Dept. of Geol. Sciences, University of Texas, Austin, Texas 78712, USA.

(5) Global tectonics and metallogeny project

The former IAGOD Secretary, Professor Jan Kutina asked to inform the IAGOD members about the Global tectonics and metallogeny project. His information you will find enclosed.

Mirko Vaněček,
IAGOD Secretary

2 Encl.

Internat. Assoc. Genesis of Ore Deposits /IAGOD/,
Appendix to Circular of June 10, 1972

Global Tectonics and Metallogeny Project,
By Jan KUTINA,
Appendix to Circular of June 10,1972,
Internat.Assoc.Genesis of Ore Deposits /IAGOD/

FTG, JDS, GJK, AG → WLK

W. L. K.

AUG 3 1972

New York, July 31, 1972

MEMORANDUM FOR: Division Supervisors
Asarco Exploration Department

Herewith are the "Conclusions and Recommendations" from a hundred page report by Dewey and Bird on "Plate Tectonics and Ore." The complete report will be reproduced and distributed later. Meanwhile you may note items of interest and possible action.

John J. Collins

John J. Collins

Encl.

cc:RJLacy
WLKurtz
RKKirkpatrick
JVDesvaux
KWhiting
MPBarnes
SAAnzalone
RLBrown
RBSprague
LPEntwistle
DMFletcher
JHCourtright

CONCLUSIONS

1. Plate tectonics successfully explains and integrates an enormous amount of geologic data. Admittedly, many of the detailed geologic corollaries will be modified in the future but it is now clear that plate tectonics holds the key to unraveling as yet exceedingly complex geologic problems.

2. The origin of nearly all categories of ore concentrations can be clearly related to processes occurring at, or near, plate margins. For the first time much of the guess-work will be removed from concepts of origin of ore.

3. The application of plate generalities to specific prospects requires the highest order of careful collection and interpretation of field data.

4. Magmatic ores associated with basic rocks

   a. High-oxide and low-sulfide magmatic ores

      (1) Podiform chrome ore in serpentine occurs in the ophiolite basement of arc-trench gaps and in subduction melange zones. Although they lie oceanward of the major calc-alkaline volcanic centers, they may overlap some volcanics despite having formed before the local volcanism. They occur within flysch and associated melange sediments. Such ores are original concentrations in the upper mantle which were remobilized above subduction zones and tectonically emplaced.

      (2) Chrome ores may occur in obducted or upfaulted ophiolite.

(3) Chrome ores associated with major differentiated magmatic sheets occur in stable (Precambrian) areas. The magma was most likely derived by partial melting of mantle at a depth of over 30 km. Below this depth chrome is mostly within pyroxene and garnet.

b. High-sulfide (pyrrhotite - pentlandite - chalcopyrite) and low-oxide magmatic ores occur, apparently within and on the landward side subduction-related volcanic belts. Sulfide deposits of this type are believed to have originated in a sulfide-rich layer of the mantle (low velocity zone?) from which a largely picritic material results from partial melting above subducting oceanic lithosphere. Such melts rarely reach the surface and, hence, such occurrences are found in deeply eroded metamorphic terrains.

c. Low-sulfide and low-oxide magmatic materials are of four types and occur in distinctive plate environments:

(1) in the outer serpentine belt (of 4.a.1. above); many (most?) of these serpentines are not rich enough in chromite to be of interest.

(2) in the tensional zones associated with initial continental rifting, as simple differentiates of tholeiitic types of rock derived from partial melting of the uppermost mantle (down to about 30 km.); e.g., Palisades Sill

(3) in ocean "hot spots" of the Hawaiian type (alkali basalts); partial melting of mantle at depths of 60 km. or more.

All of the magmatic materials associated with (2) and (3) above seem to contain no magmatic ore concentrations, even when differentiated. (However, hydrothermal ore may be associated as at Cornwall, Pennsylvania.)

5. Magmatic ores associated with other igneous rocks

a. High-oxide, low sulfide

(1) Ilmenite - magnetite ores occur in the Palabora carbonatite and may just possibly be magmatic. The carbonatite is part of a kimberlite-carbonatite suite; such rocks seem to be limited to cratonic areas. Carbonatites may originate from extreme differentiation of very stable magma chambers at depths of 60 or more km.

(2) Titaniferous magnetite (with apatite) occurs at the top of the Bushveld complex and is associated with the more feldspathic zones at the top of the differentiation series with chromite concentrations at the base. This has been described before.

(3) Ilmenite and magnetite occur with anorthosite, primarily in Precambrian areas. It is possible that a chrome-rich counterpart may occur at depth below ilmenite-bearing anorthosite in ultrabasic rock.

(4) Ilmenite and rutile, with much apatite, occur at Roseland, Virginia. Although the host roselandite is not an anorthosite, anorthosite occurs with it and seems to be in part, type (3) above.

6. Hydrothermal ores

a. Igneous activity and plate tectonics are genetically related.

b. Hydrothermal ores are mainly related to igneous activity.

c. Therefore, ore formation is related to plate evolution.

d. Most hydrothermal ores have spatial constraints with respect to plate geometry.

e. Most hydrothermal ores of Cordilleran belts were ultimately derived from the partial melting of down-going plates; sea-water might be the original source of the water of hydrothermal systems; hydraulic channels might be formed by the volume reduction when igneous rocks crystallize in this environment.

f. Hydrothermal ore fluids may also originate from degassing of mantle material in zones of crustal tension, particularly for Precambrian terrains.

g. Mississippi Valley type ores are most likely derived from dewatering of argillaceous materials. The water usually passes through and dumps its metal load in porous dolomitic carbonate rocks.

2.0 RECOMMENDATIONS

2.1 Introduction

Follow-up is suggested along several lines; these are listed under 2.2 Areas of Interest and 2.3 Concepts for Further Investigation. Much additional work is either implied within the body of the report or will come to mind as the report is read by the Asarco personnel. Because each recommendation involves a different approach, the exact manner of later work can best be decided upon in conference, when Asarco input, needs, and personnel can be integrated with this report and its suggestions. The plate tectonics team assembled for this study is strongly in favor of continuation, within the interests of American Smelting and Refining, of this powerful tool for ore finding.

2.2 Areas of Interest

Two specific prospects are suggested, based on areas for which plate tectonic analysis is advanced.

2.2.1 Western Newfoundland. Five separate portions of a thrust sheet are known, each of which makes a logical search area for chrome, copper, and manganese, in their characteristic (and separate) portions of the ophiolite suite.

a. Trout River
b. North Arm
c. Blow-me-down Mountain
d. Lewis Hills
e. Hare Bay

The five units fall within the specified size limits and can be tied to their mapped positions on the

geologic map of Newfoundland. Good-grade but small-size sulfide masses are known in one of the klippen, but little work has been done utilizing present knowledge of ophiolite stratigraphy; instead past work has almost always lumped the rocks into one catch-all: "ultrabasics." Although the targets lie in the upper plate of a far-travelled thrust sheet, substantial depths are developed in the central portions of the outliers. At least some of the prospective ground lies within concessions, but the holders often let options on their land. For instance, recent work on the York Harbour Mine, in the Blow-me-down Mountain area, was carried out by Long Lac Mineral Exploration Ltd. under option from Big Nama-Creek Mines, Ltd., which company held a mining grant and concession.

Specifically, the program would be to:

1. establish the ophiolite stratigraphy
2. trace structures
3. seek ore concentrations in hinge areas of folded horizons, such as
   a. pillow basalt-sediment contact,
   b. pillow basalt-sheeted dike contacts,
   c. within the dunite below the Moho.

   These particular areas are relatively accessible and have good outcrop exposure. A program here would give a good test to unravelling the complexities of mineralization in ophiolite belts and would, in all likelihood, have world-wide applicability.

2.2.2 King's Point, Newfoundland

This area west of Springdale embraces the old Randall Jackman prospect. Tectonically, this is a Cambrian opening ocean situation; here also, copper should be sought in the oceanic pillow basalts where sulfides are concentrated in fold hinges. Intrusions are reported in the area, adding the possibility of island arc mineralization. Forest cover is dense, but the areas of folded schistosity are known, at least in part, and regional stream sediment geochem work could check out the chances of mineralization. We have here a plate setting of the Tilt Cove (or Cyprus) type with known mineralization and known lack of modern prospecting. The limits of the area can be set using maps available at Memorial University, St. John's.

Additional suggestions are made below for further work, where definition of plate facies and ore relations have brought intriguing possibilities to light. Much office geology is still necessary, and no royalty interest areas are detailed at this time.

2.2.3 Campbellton, Newfoundland

Rhodochrosite has been reported in homoclinal, tilted fault blocks. Mineralization is said to be ten feet thick, grade unknown. Messrs. Dewey and Bird will visit this area during August and will report back on their findings.

2.2.4 Buchans, Newfoundland

It is entirely likely that the wealth of geologic detail gathered over the years at Buchans is amenable to plate analysis. It is suggested that John Dewey be authorized to visit the mine to pore over the maps with the local staff. A minimum of two days is suggested. This would be a time-card job with no claim on possible discoveries.

2.2.5 Sierra Madre Occidental, Mexico

Plate-margin volcanic action carries considerable precious metal mineralization that can be concentrated by superposed effects into the epithermal "bonanza" veins. Investigation should be carried out between the known districts, where the host volcanic rocks may contain low grade silver mineralization that is economic with open-pit mining, even though no well-marked vein systems have developed. This type of study of metal values, times of volcanic action, and migration in space can be extended to include all Cenozoic volcanism of the West Coast.

2.2.6 Klamath Mountains, Oregon and California

Late Paleozoic-Triassic ophiolites are cut by island arc volcanics and igneous intrusions and bounded on the north and south by sharp swings in tectonic trend that may reflect transcurrent faulting, perhaps of the Texas lineament type. At such crossroads should be sought ophiolite, porphyry copper, and massive sulfide types of mineralization.

2.2.7 Foothills Belt, California

This is the southern equivalent of the Klamaths, much more intensely deformed. Particularly should the greenstones be investigated for ophiolite-type mineralization. Stocks subsidiary to the Sierra-Nevada may be low-level intrusions with all the earmarks of porphyry copper bodies.

2.2.8 Cordilleran Lineaments

Strongly marked linear zones have long been identified and associated with mineralization; most famous of these is the Texas lineament. Study of the plate facies map indicates many more, all worthy of further study. For instance, the trend that joins the northern limits of the Black Hills, Big Horn, and Beartooth uplifts appears to be a left lateral wrench, not unlike the Texas Lineament. This has been called the Lewis and Clark Lineament; the fact that it passes through Butte, and possibly through the Coeur d' Alene district, and offsets batholiths and outcrops of the Belt Supergroup adds interest to a study of its history and importance.

Other, roughly east-west lineaments are known, and more are being discovered with increasing frequency. As examples, these lineaments can be cited:

a. Lewis and Clark
b. Wichita
c. Texas
d. Parras (Central Mexico)
e. Cayman (Mexico-Guatemala)

f. Oquirrh-Uinta (N 40° 40')

g. Deep Creek - Tintic (N 40°)

h. Wah Wah - Tushar (N 38° 40')

Similar east-west trends are reported in Nevada, and offsets of the mid-continent gravity high are said to be alignments of mineral districts. These lineaments may represent deeply buried, long-lived, fundamental dislocations that would have had effects additional to channeling base metal mineralization. For instance, such faults may also have been the plumbing system for mercury or for abnormal heat flow that would affect the leaching of U_3O_8 in source rocks and precipitation in basin sediments. This theory can be tested in the Powder River Basin or in the Big Bend Area of Texas.

2.2.9 Cocos Ridge

This is a spreading axis that is being overridden by the continental margin at a trench-trench-ridge triple junction off the west coast of Panama. It should be supplying copper to the Panamanian volcanic belt.

2.2.10 Pinchi Belt, British Columbia

A "fossil" oceanic crust zone here should be studied and prospected for copper, asbestos, and chrome, in the same manner as for the ophiolites of Western Newfoundland.

2.2.11 Thermal Prospecting

Thermal power is becoming more and more important. In some parts of the world the thermal waters are normally

rich enough in various salts to be economically interesting. The chemical engineering problems of recovering these salts are severe, but we understand that studies are underway to exploit some of these resources, particularly for the more common Ca and K salts in the Salton Sea area. We think that such technology bears watching. The economic recovery of NaCl, KCl, $CaCl_2$ and perhaps Mn might all be possible now. Other more exotic metals may be recovered later, expecially if combined with the production of power.

Thermal areas are of the following types:

a. Residual heat after volcanic activity associated with subduction. If our concepts are correct that hydrothermal fluids are mobilized off of subduction zones after igneous activity, then the areas where salt-rich fluids are rising along warm but crystallized intrusives should lie just trenchward from or perhaps among the main volcanoes of a chain.

   Examples: Cordilleran and island arc chains, such as Andean, Japanese and Mediterranean. The Aleutian-Alaskan Peninsula chain and Central America seem to be particularly interesting.

b. Residual heat from volcanoes associated with heat plumes along with heat from the plume itself. The heat is not known to carry appreciable mineralization with it, but the possibility should not be discounted.

   Examples: Oceanic, Hawaiian Chain; continental, Yellowstone (?).

c. Heat associated with plate accretion. Thermal waters associated with accreting or trailing edges of plates are apparently always rich in various salts including sulfides and more exotic metals. The most obvious metal-rich thermal areas seem to be of this type.

Examples: Salton Sea brines, Red Sea thermal deeps, and, basically, any zone of plate spreading, such as the Mid-Atlantic ridge or the East Pacific rise in the Gulf of California.

d. Heat of unknown origin associated spatially with old subduction zones (possibly low temperature fluids tapped by transform crustal breaks). Such thermal waters may be relatively "clean," but mercury may be deposited from them.

Examples: Sonoma and other thermal areas of the California Coast range.

2.3 Concepts for Further Investigation

The process has just begun whereby plate facies and ore are being related in time and space. Because these studies are in their infancy, more time was devoted to the "model" than to prospecting targets. As a result, the pin-pointing of prospects lagged, even as faith in the eventual use of plate tectonics in ore search increased.

It is now possible to sort out the unlike elements that earlier were lumped into metallogenic provinces and epochs and to define them properly in terms of plate facies, time of facies development, and time of ore introduction. Petrology, for instance, is spelled out as all-important, not merely as an

academic topic that embraced the host rock, but as one of the keys to facies definition. "Favorable host rock" is changing from an empirical litany to a useful part of the rock-ore spectrum in which all gradations and inter-relations are understood.

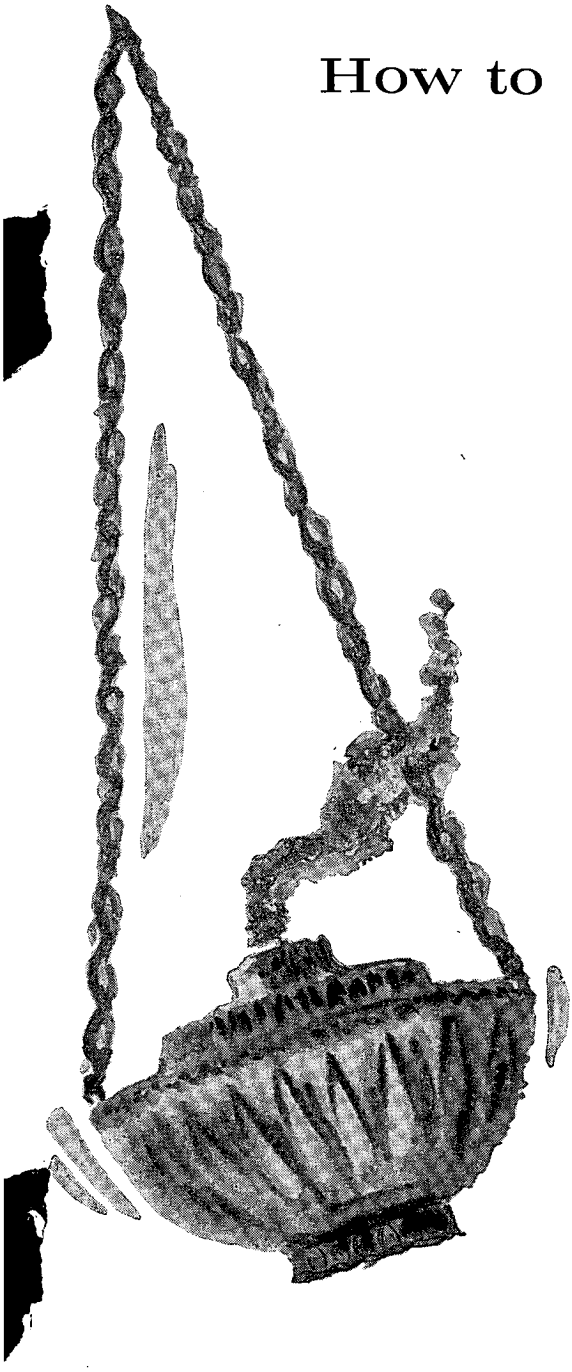
Topics which can profitably be investigated further are many:

a. Continental Lineaments
b. Ultrabasic masses intruded into ophiolite belts
c. Time and space relationships of island arc massive sulfides to porphyry copper deposits
d. Disposition of metal-bearing fluids that reach the surface
e. Topography of Benioff zones
f. Location of fossil ridge zones
g. Age determination evaluation
h. Similarities and differences between pre-plate-development ore (ca 2,000 million years ago) and plate margin-related ore
i. Further detailing of the plate history of intriguing ore belts
j. Continental sedimentation and sedimentary ore development
k. Development of diatremes, carbonatites, and similar phenomena often related to exotic ore deposits
l. Determination of the optimum relation of location of poles of spreading, speed of spreading, amount and type of magma poured out, and amount of hydrothermal fluid entrapment
m. Recognition of tensional zones above subduction zones and relation to ore development

File Plate Patrick

Geophysics — Continental Growth
J. Tuzo Wilson 1959

How to save 77 years



The boy Galileo sat in the sanctuary of Pisa's great cathedral, observing the movement of a lamp which had been set swinging by a sudden gusty draft. The chain by which it was suspended from the high ceiling was of such a length that the arcs decreased but slowly. Strange thing, though. No matter how far the pendulum swung, its movement consumed the same time. Galileo made a note of that. The year was 1581.

The old man sat at his writing desk, sixty years and a thousand disputes later, writing down a new theory. The regularity of a swinging pendulum might be combined with a spring mechanism to improve the unreliable clocks of that day. So Galileo scribbled on, and did nothing more about it. After his death Huygens took the notes and invented the pendulum clock. *Seventy-seven years had elapsed since the boy made the observation upon which it was based!*

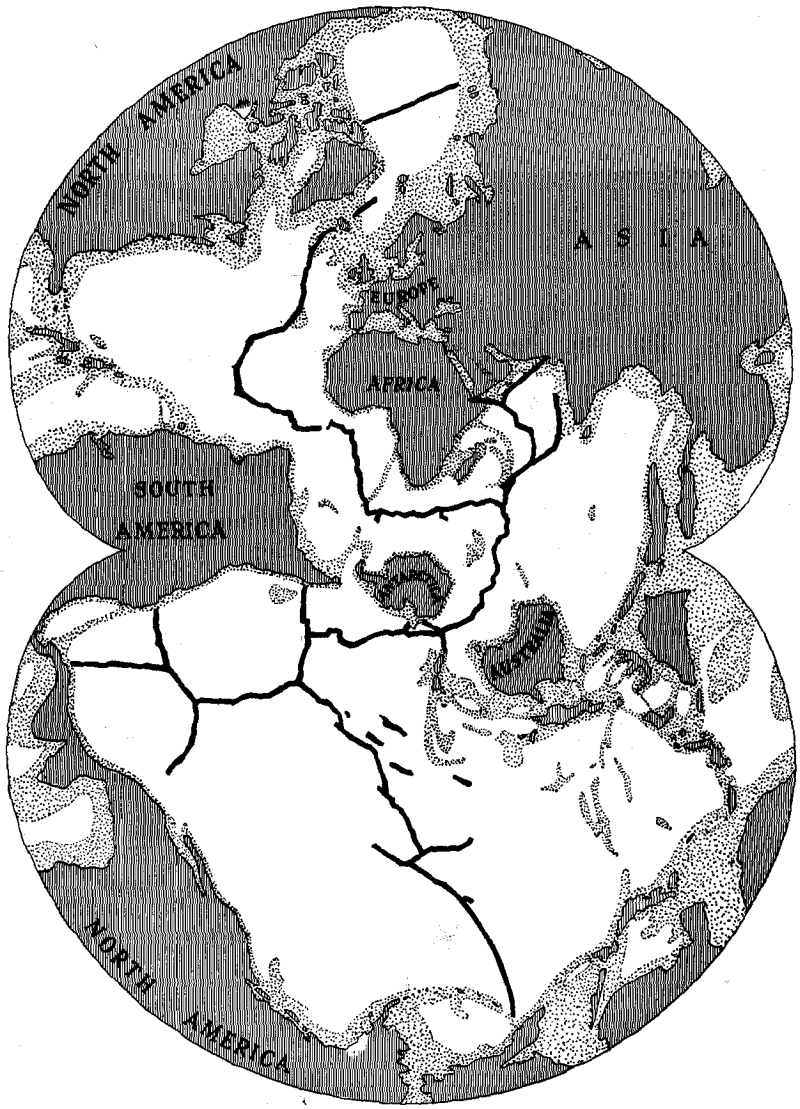
The creative thinker today still need not have a specific use in mind when, by equation or formula, he branches off from the accepted to the hitherto unknown. The classic invention of this decade, the transistor, evolved in the Bell Telephone Laboratories as scientists sought a deeper understanding of semiconductors. On the other hand, another great invention, the feedback amplifier, came from the creative mind of one Bell Engineer faced with a specific problem.

Current Bell Laboratories activities—in such areas as data transmission, radar and submarine cable development—call for the coordinated efforts of all types of thinkers and all types of approaches. One type complements another.

Today, seventy-seven years would not have elapsed between the swinging lamp and the swinging clock pendulum—certainly not at Bell Labs, where ideas, though not rushed, are carefully advanced toward fruitful application in national defense, industry and communications. An important part of this harvest is the efficiency of America's telephone service, unequalled anywhere else in the world.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT



Legend

Mid ocean ridges

Ocean depths less than 1500 fathoms

Land

FIG. 2. FRONTISPIECE. It seems probable that a continuous ridge a few hundred miles wide, from 10,000 to 33,000 feet high and perhaps 40,000 miles long, winds its way across the central ocean floors. The discovery, only two years ago, of the continuity of this, by far the greatest mountain range on Earth, is an interesting commentary upon the state of our knowledge about some parts of the Earth. (Invert in order to view the Pacific Ocean clearly).

AMERICAN SCIENTIST

SPRING MARCH 1959

GEOPHYSICS AND CONTINENTAL GROWTH[1]

By J. TUZO WILSON

[1] A Sigma Xi National Lecture, 1957–58.

Plate Tectonics WLK

Also, oil and mining companies are inter-

Please Turn to Page 17, Column 1

From: J. J. Collins

To: Atty Wm Kurtz
Tucson

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Airforce mail

File Plate Tectonics
(Asarco copy (stamped by HS))

AGREEMENT made this 10th day of June, 1971, between JAMES R. DUNN & ASSOCIATES, INCORPORATED, a New York corporation, with an office at Averill Park, New York, (hereinafter referred to as "Dunn") and AMERICAN SMELTING AND REFINING COMPANY, a New Jersey corporation, with an office at 120 Broadway, New York City, New York (hereinafter referred to as "Asarco")

W I T N E S S E T H :

Recitals:

Dunn is a geologic consulting firm engaged in prospecting. Professors John F. Dewey and John M. Bird are expert in the field of "Plate Tectonics" (as that term is understood in geology) and under exclusive contract to Dunn for rendering such consulting services as utilize "plate tectonics" concepts in prospecting for metallic minerals and asbestos. Asarco is in the mining business and desires to utilize the services of Dunn and said experts as an aid in locating ore deposits.

In consideration of the premises, the parties agree as follows:

1. Term.

This agreement shall endure for the term of one year from the date hereof, and at Asarco's option, to be exercised by written notice to Dunn, may be extended for an additional year on the same terms as herein provided, but with the option in Asarco for Dunn's services on an expanded basis greater than the limits herein provided for but subject to Dunn's capacity to perform on any proposed expanded basis.

2. Scope of Work.

The parties desire to develop plate tectonics research in aid of location of orebodies by an expenditure not exceeding the total of fifty thousand dollars to be made by Asarco under the terms hereof. For that purpose the parties shall consult with each other and either party may submit to the other for its consideration such areas for study as it believes suitable for the purposes hereof, and Dunn shall recommend to Asarco such areas as its said experts deem particularly favorable for application of the principles and theories of plate tectonics in the discovery of orebodies. Asarco shall select and determine the area or areas within or pertaining to which the services hereunder by Dunn shall be performed. During the term hereof such areas shall be limited to North America and the minerals sought shall be limited to metallic ores and asbestos, and during the entire term hereof shall exclude (unless waived by Dunn) the following areas and subjects:

a. "Grenville" rocks in New York State.

b. Paleozoic rocks fringing the Adirondacks in New York State.

c. A conceptual study of refolds, leading to analyzing prospects and mines in doubly folded regions; the supporting members of the refold syndicate to receive the results of the study and to have exclusive use of the method in prospecting for one year following the submission of the report.

d. The New England States.

e. Newfoundland.

During the term hereof and subject to the foregoing limitations and exclusions, Dunn and said Professors Bird and Dewey will devote their services and expert knowledge in the said field of plate tectonics exclusively to Asarco insofar as they pertain to the subject matter of this agreement, provided Asarco approves areas for the rendition of said services hereunder and substantial expenditures therefor but not exceeding the above mentioned monetary maximum.

3. Reports and Confidential Information.

At least thirty days prior to the expiration of the year's term hereof, Dunn shall deliver a written study and report, including inter alia, the following subject matter:

a. A clear exposition of the relation of ore bodies to "plate elements";

b. A table or diagrammatic presentation of ore introduction at various stages of development of the several types of continent and island arcs;

c. A map presentation of plate elements and ore for at least two orogenic belts;

d. A statement of the meaning of the above to the planning of exploration campaigns;

e. Recommendations for prospecting techniques and targets consistent with Asarco's interest.

In addition to the above, Dunn will render such interim reports to Asarco as the latter may request.

Dunn and said Professors Bird and Dewey shall be free to publish papers of a general nature concerning plate tectonics but shall not publish any information or discussion concerning location or localization of ore deposits by relation to plate tectonics for at least one year after the term hereof without Asarco's written consent. All information about location or localization of ore deposits, whether actual or speculative, which result from the work hereunder, shall be the property of Asarco and shall not be disclosed or discussed without the written consent of Asarco, unless the same pertain to recommended areas rejected by Asarco, as hereinafter provided. Dunn and Professors Bird and Dewey severally agree to use their best efforts to maintain such information in confidence so long as the same remain unpublished by Asarco and Asarco has not given its written consent to its disclosure.

4. Compensation to Dunn; Billing; Records.

Prior to initiation of each research project hereunder, the parties will agree on the approximate costs to be incurred by Asarco in connection therewith, but subject to expenditures thereon exceeding such approximation if unforeseen factors intervene. In the latter case, Dunn shall advise Asarco, in advance if possible, of the excess in costs that will be incurred and be guided by Asarco's instructions in limiting or terminating the proposed work for the purpose of reducing the costs thereof. Dunn shall be

compensated for its expenditures during each calendar month, on the following basis:

a. All out-of-pocket costs for travel expenses, computer services if any, materials, and all other direct costs other than labor, shall be reimbursed at Dunn's cost.

b. Payroll costs for summer geologic employees and all other direct labor will be reimbursed at Dunn's cost plus 30%.

c. The services of senior geologists shall be charged to Asarco by Dunn at up to the rate of $200 per day.

The foregoing charges shall be deemed to include all the compensation of Dunn hereunder, except for the possible additional compensation to Dunn by way of royalty, under the terms of Article 5 below. Dunn shall render monthly invoices to Asarco promptly after the end of each calendar month for all of the above charges incurred during such month and Asarco shall promptly pay the same. Asarco shall have the right at all reasonable times to inspect all records and data of Dunn in verification of all charges made, and to make copies and extracts thereof, and Dunn agrees to make and keep written records of all such costs and all pertinent evidentiary data in support thereof and maintain the same for Asarco's inspection and audit for at least one year after the termination of this agreement.

5. Additional Compensation to Dunn by Way of Royalty.

In the course of its work hereunder Dunn shall make recommendations to Asarco for mineral prospecting of areas not exceeding approximately 100 square miles. Such recommendations shall be accompanied by a detailed geologic description of the area, the outer boundaries of the area recommended, and such maps, plans or sketches as will be helpful in explanation and support of the text of the recommendation. Asarco shall be free to reject in whole or in part any recommendation made by Dunn, and upon request of Asarco, Dunn will confer with Asarco and discuss in any further detail that may be desired, the reasons for its recommendation. If Asarco does reject a prospecting area recommended by Dunn and if Asarco should within two years after the presentation to Asarco of such recommendation engage in prospecting for minerals therein, such prospecting by Asarco shall be deemed to be done pursuant to the recommendation of Dunn and the terms hereof shall apply as in the case of a recommendation made by Dunn and accepted and performed by Asarco unless Dunn has already entered into a remunerative relationship with another person or firm regarding the recommended area. Asarco shall owe no duty to Dunn to perform any work in a recommended area, or to continue with any work program which may have been initiated, and if Asarco rejects any recommendation by Dunn, or accepts a recommendation by Dunn but doesn't begin exploration work within the recommended area within a year after said presentation to Asarco or discontinues work therein for more than a year after having begun the same and such delay in beginning or continuing the work is not excused by causes beyond

the reasonable control of Asarco, then Dunn shall be free to recommend any such area to others than Asarco and free of any obligation hereunder to Asarco with respect to such area. If Asarco rejects a recommended area, or if it accepts any recommendation but fails to obtain any property interest therein within one year after such recommendation is accepted by Asarco or if Asarco abandons all property interests it may have obtained in such recommended area pursuant to its said acceptance, then upon the expiration of two years after any such event and without Asarco obtaining any property interest in such area in said two-year period, Asarco shall be free of any obligation hereunder to Dunn with respect to any such area, provided that said two-year period shall commence upon Asarco's giving Dunn notice of such event. Notwithstanding the foregoing, if an area recommended by Dunn encompasses a substantial portion of a known mineralized district in which commercial mining operations are then being conducted, or consists in substantial part of an area within such a mineralized district, the foregoing two year limitation shall not apply to Asarco in case of Asarco's rejection of a Dunn recommendation covering such area or Asarco's failure to obtain or its abandonment of any property interests therein following its acceptance of such recommendation within the periods aforesaid, and Asarco shall be free of any obligation hereunder to Dunn with respect to any property interests acquired by Asarco within said two-year period after the occurrence of any of the aforesaid events, in such recommended area, if the dominant, primary cause of Asarco's

acquisition of any property interest in such recommended area within said two-year period was other than Dunn's recommendation or any work done by Asarco therein pursuant thereto. Asarco's determination, if made in good faith, shall control and be binding on the parties hereto, with respect to the factual questions whether a recommended area encompasses a substantial portion of said known mineralized district or consists in substantial part of an area within such a district, and whether Asarco's re-entry and acquisition of any property interests within such recommended area within said two years was dominantly and primarily caused by the recommendation made by Dunn.

Areas recommended by Dunn shall not include properties in which Asarco now has or may hereafter acquire any interest (other than any acquisition made by Asarco and covered hereunder), nor in any areas within a radius of ten miles of any such properties. If Asarco desires to employ Dunn within any such excluded areas it will do so by separate agreement with Dunn on a mutually acceptable basis.

If Asarco recovers minerals from an area recommended by Dunn, and unless such area is excluded by the aforesaid terms from imposing any obligation on Asarco to pay Dunn a royalty for any minerals recovered therefrom, Asarco shall pay Dunn a royalty based on net profits as herein defined, as follows:

a. If the mineral interest in the lands from which the minerals are recovered are privately owned at the time of the Dunn recommendation, Asarco will pay Dunn a

royalty of five per cent of net profits, with the option in Asarco to purchase such royalty interest from Dunn, at any time, for the sum of $2,000,000, U.S. currency; said royalty to be paid quarterly, or as otherwise mutually agreed.

b. If the mineral interest in the lands from which the minerals are recovered are owned by the governmental authority having jurisdiction thereof, at the time of the Dunn recommendation and such lands are open for staking or claiming without the need of Asarco's purchasing from third parties any prior mineral rights therein of such third parties, Asarco will pay Dunn a royalty of ten per cent of net profits, with the option in Asarco at any time to purchase half of such 10% royalty for $2,000,000, U.S. currency, and at any time to purchase the remaining half or 5% royalty for the sum of $3,000,000, U.S. currency.

The definition of net profits and the other obligations of the parties with respect thereto are set forth in Schedule A hereto attached and made a part hereof.

Dunn agrees not to recommend closely adjacent areas exceeding 100 square miles in total and recommendation of such areas by Dunn will not serve to give Dunn any royalty rights hereunder in the event Asarco recovers any minerals therefrom, and in the case of such areas in total exceeding said limit in size, Dunn's compensation shall be confined to the sums set forth in Article 4 above.

Notwithstanding that the intent of the parties to this agreement is that the specific areas recommended by Dunn to Asarco for mineral prospecting shall each not exceed 100 square miles, it is understood that there may arise occasions when Dunn will deem areas larger than said 100 square miles worthy of recommendation hereunder, and in such case, Asarco, if in its sole discretion it so decides, may from time to time waive in writing such limitation in regard to certain areas proposed by Dunn and all the provisions of this agreement shall then apply to such areas.

Any sale or transfer by Asarco of any property charged with the payment of royalty to Dunn under the terms hereof shall not affect such royalty and the same shall continue to be a royalty interest in such property and continue to be payable by such transferee, and its or his successors and assigns.

6. Status of Dunn.

Dunn has the status of an independent contractor hereunder, and shall not be deemed an agent or employee of Asarco, nor shall any of its employees or agents, including Professors Bird and Dewey, be deemed to be employees or agents of Asarco. It shall comply with all laws in performing its services hereunder, including such items as workmen's compensation insurance coverage, unemployment insurance expenditures, etc. and all such costs incurred hereunder shall be reimbursable by Asarco to Dunn.

7. Notices.

Any notice hereunder shall be in writing and may be served by registered mail. The time and act of posting such notice shall be deemed the time and giving thereof. Such notice shall be addressed to the party to receive the same, as follows:

If to Dunn:

James R. Dunn & Associates, Inc.
Box 158
Averill Park, New York 12018

If to Asarco:

American Smelting and Refining Company
120 Broadway
New York City, New York 10005
Attention: Exploration and Mining
Departments.

Either party may give notice to the other of different addresses or additional addresses to which any such notice shall be sent by registered mail.

8. Arbitration Clause.

In case of any dispute hereunder between the parties, the same shall be submitted to, and be determined by, arbitration in accordance with the rules of the American Arbitration Association. The arbitration shall be conducted in New York City.

9. General.

The article headings are intended for convenience only and shall not affect the interpretation of this agreement.

This agreement shall be governed by the laws of New York.

IN WITNESS WHEREOF, the parties have executed this agreement as of the date first above written.

JAMES R. DUNN & ASSOCIATES, INC.

By _____
President

AMERICAN SMELTING AND REFINING CO.

By _____
Vice President
Director of Exploration

Approved as to form
LEGAL DEPARTMENT
BY _____ 8/12/71.

In consideration of American Smelting and Refining Company entering into the above agreement, we John F. Dewey and John M. Bird, do severally agree to comply with and perform the obligations imposed upon each of us by the terms of the above agreement.

John F. Dewey

John M. Bird

JHC

FORM SL-1035-A 1 M 4-70

KEEP THIS ON TOP

File No.

From to

Subject: PLATE TECTONICS

Facts and theories on the Andes

AUGUSTO GANSSER

Twenty-sixth William Smith Lecture

Plate Tectonics

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