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W.E.S.

JUN 30 1969

J.H.C.

JUN 20 1969

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

June 20, 1969

MR. W.E.S.
READ AND RETURN
PREPARE ANSWERS ____ HANDLE ____
FILE ✓ INITIALS ____

TO J.H. Courtright

FROM J.D. Sell

Communication and Literature Research
Exploration Technique (?)
Deeply Buried Plutons

As a follow-up on my File Memorandum of April 14, 1969, the following notes are submitted concerning the possible usefullness of age-dating techniques in determining the presence of a deeply buried pluton (or the equivalent lateral dimension in that we are discussing a three-dimensional model).

Several exchanges of letters have been made with Dr. Zell Peterman, Branch of Isotopic Geology, Denver Federal Center, who does much of the Rb-Sr age work for the Survey. Several items were brought out in the correspondence: 1)biotite is much more readily reset than hornblende, 2) a knowledgeable biotite-hornblende sampling pair program would be necessary for interpretation of data, 3)interpretation of geologic history prior to emplacement time of suspected younger intrusive is essential, 4)the higher the number of plutons or structural events involved in the area, the greater complexing of factors which will cloud the interpretive results, 5)total (whole) rock Rb-Sr ages are commonly not affected by thermal events alone, but may be highly disturbed by hydrothermal events, and 6)mineralization often highly disturbes age-dates.

Peterman also recommended two papers for further insight into this problem. Abstracts for both papers are attached.

The Hart (1964) paper is a study involving a Tertiary (54 my) pluton intruded into Precambrian (1200-1400 my) terrane. The intrusive is several miles in diameter. Hart found in sampling the Precambrian terrane outcrop outward from the intrusive

1) Rb-Sr ages of potassium feldspar is not affected beyond 50 feet.
2) K-Ar ages of hornblende is relatively unaffected beyond 100 feet.
3) K-Ar ages of potassium feldspar is less affected than K-Ar biotite ages in the first 1,000 feet.
4) Rb-Sr and K-Ar biotite ages undergo a complete transition from unaffected Precambrian ages beyond one intrusive width (10,000 feet) from the contact to strongly affected ages near the contact.

The Hanson (1967) paper involved studies on very old rocks (800-2600 my) and came up with the order of "relative stability of mineral ages in a contact zone is hornblende K-Ar > muscovite Rb-Sr > muscovite K-Ar > biotite Rb-Sr > biotite K-Ar, although for the micas the Rb-Sr and K-Ar ages are essentially concordant."

In an attempt to resolve some of the data and apply it to the age-dating available at Silver Bell, as discussed at lunch the other day, we are reminded that the K-Ar dates published for units at Silver Bell are not totally in agreement with the field information. Conflicting ages are given for the Quartz Monzonite and the age differences are resolved back to mineralization, weathering, leaching, etc., factors. A recheck of the K-Ar dates show they range from 57 to 67 with a ±2 my factor. In rather close dating of this type a small error could account for the apparent reversal of units, and by manipulation of the ±factors we can come up with a similar age dating sequence as that revealed in the geologic field studies.

Field Relations	First Figure K-Ar dates	± Manipulation
Quartz Monzonite(youngest)	Dacite 57.7 ±2.0(biotite)	
Mt. Lord Ignimbrite	Mt.Lord 59.7 ±1.8(feldspar)	Mt. Lord - 57.9
Silver Bell formation	Alaskite 64.6 ±2.5(biotite)	Dacite - 59.7
Dacite	Q.Monzonite 67.1 ±2.7(biotite)*	QM-64.4 (or 61.2)
		Alaskite 67.1
Alaskite (oldest)	(*lowest QM date given is 63.4 ±2.2)	

(NOTE: All age-date figures from Mauger, R.L., 1966, PhD Dissertation, U of A, ASARCO library.)

The Quartz Monzonite is out of place in either the first figure or the ± manipulation schemes. As pointed out earlier, the large number of events within the geologic history of the area tend to complicate and cloud any interpretation of dating values.

In view of the field data, there seems little doubt that the Alaskite is indeed the oldest unit of this group, and as a consequence of the history of the area, the K-Ar date of the Alaskite may have been strongly affected by these later events.

See Wrangers paper attached

Apparently lost in the publications of the Silver Bell district is a whole rock Rb-Sr date of 112 ±6 my for the Alaskite. This age (late Early Cretaceous) is very compatible to the known history of the area, being earlier than the Silver Bell formation activity sequence.

In resolving the two Alaskite dates in terms of the literature and field studies as discussed above, it can be strongly suggested that the whole rock Rb-Sr date of 112 my is the emplacement date of the Alaskite and the biotite K-Ar date of 65 my (late Late Cretaceous) is a reset date as an effect of the later Monzonite intrusive. The Dacite and the Mt. Lord Ignimbrite undoubtedly have also been affected and their emplacement date reset by the Monzonite episode.

As stated in the literature, the sample site for the Alaskite was some 4000 feet away from a known Monzonite outcrop (small dikes excepted). If by chance the only outcrop available was the Alaskite sample area, and the remaining area was covered by alluvium and post-ore volcanics, the Alaskite data of reset dates could be utilized in postulating the proximity of a heat and metallizing source in the district. With other observations such as the amount and type of alteration in the Alaskite, mineral belt analysis, structural continuity into the area, etc., the discrepancy in the isotopic dates would be an important addition to the overall study and programming continued exploration activity in the area.

James D. Sell

James D. Sell

JDS:lzb
Encl.

A PETROGRAPHIC AND GEOCHEMICAL STUDY OF SILVER BELL AND PIMA MINING DISTRICTS PIMA COUNTY, ARIZONA

by

Richard L. Mauger

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF GEOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 6 6

In basement library - ASARCO

TABLE II--Continued

Silver Bell District				
quartz monzonite (mineralized), whole rock PED-3-63 El Tiro Pit 32° 25.7' N, 111° 32.2' W	0.83	0.7103	65	0.7096 ± 0.0002
alaskite, whole rock PED-22-59 32° 24.8' N, 111° 33.1' W	3.40	0.7133	64**	0.7103 ± 0.0003
	whole rock Rb-Sr age is less than 112 ± 6 m.y.			0.708***

constants: $Rb^{85}/Rb^{87} = 2.59$

$\lambda_{\beta} Rb^{87} = 1.39 \times 10^{-11}$ yr.$^{-1}$

*All errors reported as deviations from the means of all analyzed samples within the 66% confidence interval.

**K-Ar age of alaskite, assumed to be the true age.

***Initial Sr^{87}/Sr^{86} ratio assumed to give maximum whole rock Rb-Sr age.

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J. D. SELL

THE PETROLOGY AND ISOTOPIC-MINERAL AGE RELATIONS OF A CONTACT ZONE IN THE FRONT RANGE, COLORADO[1]

S. R. HART

Department of Terrestrial Magnetism, Carnegie Institution of Washington,
5241 Broad Branch Rd., N.W., Washington 15, D.C.

and

Department of Geology and Geophysics, Massachusetts Institute of Technology
Cambridge, Massachusetts[2]

ABSTRACT

Precambrian rocks of the Front Range, Colorado, have been studied for mineralogic and geochronologic changes in a zone adjacent to a Tertiary (54 m.y.) intrusive stock. The country rocks are high-grade gneisses schists, amphibolites, and pegmatites. The only mineralogic change attributable to the contact heating takes place at a distance of one-tenth an intrusive width, where microcline changes to orthoclase. This change occurs by conversion of a highly triclinic microcline directly to orthoclase, over a distance of less than 100 feet. Study of the sodium content of the orthoclases reveals no change with distance, despite the strong thermal gradient.

The Rb-Sr and K-Ar ages of biotites undergo a complete transition from unaffected Precambrian ages beyond one intrusive width from the contact (10,000 feet) to strongly affected ages near the contact. The K-Ar ages of hornblende are relatively unaffected beyond the first 100 feet. The K-Ar ages of potassium feldspar show variable response, being less affected than the biotite K-Ar age for the first 1,000 feet. The Rb-Sr ages of the potassium feldspar are apparently unaffected beyond about 50 feet.

Quantitative interpretation of the biotite K-Ar and Rb-Sr ages in terms of heat flow and kinetic models shows that the data can be fitted to a wide variety of models. This treatment indicates essentially identical activation energies for the argon and strontium in the biotite, with the diffusion coefficients of the strontium being a factor of 5 smaller than that of the argon. Reasonable heat-flow models suggest a maximum value for the activation energy of about 30 kcal/mole.

INTRODUCTION

Many of the areas in which extensive age-determination work has been done have been shown to have metamorphic histories. In these areas, there is seldom complete agreement among all the various isotopic-mineral ages. The resulting discordant age patterns are also different from area to area. In addition to the information about absolute age, these patterns contain a great deal of information about temperature histories and metamorphic rate processes.

In these regional metamorphic areas, it is generally impossible to relate the age patterns to any specific environmental parameters. Temperatures can be only inferred from the mineral assemblages. Usually, by the time reliable indicators of metamorphic grade develop, all but the most resistant minerals will have lost any evidence of pre-metamorphic age. The classic example of this was reported by Tilton, Wetherill, Davis, and Hopson (1958) from the Baltimore gneiss domes of Maryland. Here the micas consistently gave Paleozoic ages, but the true Precambrian age for the domes was established with zircon U-Pb and feldspar Rb-Sr ages.

[1] Manuscript received December 28, 1962.

[2] M.I.T. Age Studies No. 42.

Geochimica et Cosmochimica Acta. 1967, Vol. 31, pp. 1119 to 1153. Pergamon Press Ltd. Printed in Northern Ireland

J. D. SELL

Kinetic studies in contact metamorphic zones

G. N. HANSON* and P. W. GAST†
Department of Geology and Geophysics, University of Minnesota
Minneapolis, Minnesota

(*Received* 29 *December* 1966; *accepted in revised form* 13 *February* 1967)

Abstract—The effects of thermal metamorphism on mineral ages have been investigated near the contacts of two basic intrusives. Rb–Sr and K–Ar ages of biotite, muscovite and potassium feldspar and K–Ar ages of hornblende from the Snowbank granitic stock near the contact with the Duluth Gabbro in Minnesota and Rb–Sr and K–Ar ages of biotite and K–Ar ages of hornblende from amphibolite near the contact with a quartz dolerite dike in the Beartooth Mountains in Wyoming are the basis of the kinetic studies. The Snowbank stock is 2·60 billion (10^9) yr old and was transgressed by the Duluth Gabbro 1·05 billion yr ago. The gneisses and amphibolites in the Beartooth Mountains were subjected to metamorphism 2·6 billion yr ago and were intruded by the dolerite dike, 50 m thick, approximately 800 million yr ago.

Volume diffusion and zero order and first order chemical reaction rate models are used to describe the rate of loss of the radiogenic strontium and argon from the minerals. The chemical reaction rate models may apply if the rate of loss is controlled by recrystallization. It is assumed that the Arrhenius relation describes the temperature dependence of the rate constants and diffusion constants over the range of temperatures considered, and the effect of heating on the rate of loss of daughter products is estimated by numerical integration of the time-dependent temperature curves based on Jaeger's heat-flow model for basic igneous intrusives infinite in two dimensions, such as dikes and sills.

The loss of radiogenic argon and strontium from biotite took place over a range of temperatures from 720 to 450°C near the Wyoming dike and over a range from 500 to 350°C near the Duluth Gabbro. If the loss of radiogenic daughters is attributed to a simple volume diffusion mechanism, an activation energy of 50–75 kcal/mole is indicated. For a zero order reaction rate model an activation energy of about 30 kcal/mole is required and for a first order reaction rate model an activation energy of about 50 kcal/mole. The loss of argon from hornblende took place at higher temperatures than the loss from biotite. The activation energies for the hornblende models may be higher than the activation energies for the respective biotite models.

The relative stability of mineral ages in a contact zone is hornblende K–Ar > muscovite Rb–Sr > muscovite K–Ar > biotite Rb–Sr > biotite K–Ar, although for the micas the Rb–Sr and K–Ar ages are essentially concordant.

INTRODUCTION

IN THE laboratory it has been possible to reproduce almost all the conditions found in nature except time. Thus, the determination of the kinetic parameters of a given reaction in the laboratory is limited to reactions which proceed at a rate fast enough so that a measurable effect can be obtained within a matter of hours or days or at most a few years. Many reactions of interest to geologists, however, are so sluggish that laboratory measurements are not feasible without accelerating the reaction by

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† Present address: Department of Geology, Lamont Geological Observatory of Columbia University, Palisades, New York.

WES, BEK 4/21 ~~Exp. Misc~~

J.H.C.

APR 14 1969

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

April 14, 1969

W.E.S.
APR 10 1969

FILE MEMORANDUM

TO: Mr. J.H. Courtright

FROM: Mr. J.D. Sell

Exploration technique (?)
Deeply Buried Plutons

A recent article in USGS Prof. Paper 600-A, p. A-110, entitled, "Chronology of Emplacement of Mesozoic Batholithic complexes in California and Western Nevada" perhaps adds a tool in the search for deep intrusive complexes capable of being hosts for copper-moly deposits. To quote the article:

> "A granite body emplaced into an older plutonic terrane was shown to exhibit a pronounced effect in disturbing or resetting the mineral ages in the older plutons. In fact, in the older terrane at distances from the contact equal to the dimensions of the intruding body, the K-Ar and Rb-Sr ages of biotites were reset to the age of the intruding unit. Because of the better argon retention properties of hornblende this same effect was noticeable for only half this distance."

The first part of the quote is well documented by geochronologists, and the remainder of the quote opens another dimension in the search for deeply buried ore deposits. For example, if an area of weakly altered rocks were found (perhaps like the Copperosity area, See JEKinnison memo dated April 4, 1969), and it might be suspected that deeper intrusives be present then the premise could be tested by K-Ar dating of biotites and hornblendes in the surface exposures. Outside the altered zone the age of the biotites and hornblendes should be essentially the same but within the zone the dates would be discordant depending upon the size and sub-surface depth of the younger intrusive. A younger intrusive of several thousand feet in plan emplaced several thousand feet below the present surface outcrop of the older pluton would reset the K-Ar date of the biotite (to a younger age) in the older pluton but would not effect the K-Ar date of the hornblende in the older pluton.

No further biteroture research has been made, nor talks with the U of A people, but with the precision now being made with age dating of samples it is probably that some confidence limit could be established on interpreting complex intrusive areas.

James D. Sell by J.R.
James D. Sell

JDS:ir

4/10/69 235

Please copy for ES

J.H.C.

APR 10 1969

Air Mail

April 9, 1969

Mr. R.J. Lacy
Salt Lake City Office

Deep Seated Tectonic Trends

Dear Mr. Lacy:

Thank you for handing me a copy of Marvin Barnes' memo of March 25th to you on the subject of "Proposed Special Project, Nevada, Utah, Arizona, Integrated Regional Exploration Studies." I recognize in this a broader outline of the subject that we discussed in your office two months ago. Now I see that sedimentation and stratigraphy from the Cambrian to the Pliestocene will be important including the construction of paleotectonic maps and the extension of the basement trends outside the area of published magnetics. This sounds to me like many man years of office studies of background information. I would prefer to see more emphasis on mineralization and field work.

As soon as Mr. Barnes completes the aeromagnetic interpretation of the deep seated tectonic trends in Western Nevada we will arrange a conference between him and one or more of the staff of the Regional geologic office. This conference should result in the choice of the optimum target area in Western Nevada for a field trial. If this choice is authorized as a project, we will assign Mr. Barnes on a temporary basis to a Regional office for administrative purposes and men and material. The project will not be assigned to someone else. We want Mr. Barnes to have the opportunity to test his theories as soon as possible. As our Chairman has said, "Go to the orebody first and to the background work later on." I trust that Mr. Barnes will be able to put in a full field season this summer. Please let me know how soon I can schedule a conference with the Regional Field Geologists as I would hope to be present. With best wishes,

Sincerely yours,

John J. Collins

CC: JHCourtright ✓
MBarnes

GEOPHYSICAL DIVISION
3422 South 700 West
SALT LAKE CITY, UTAH 84119

March 25, 1969

MEMORANDUM TO R. J. LACY:

PROPOSED SPECIAL PROJECT
NEVADA, UTAH, ARIZONA
INTEGRATED REGIONAL EXPLORATION
STUDIES

General Concept:

For some time now members of our staff have been pondering the possible implications that deep seated tectonic trends and lineations might have a positive and definitive correlation to major base metal mineralization in the Basin and Range province. At present we are unwilling to accept the possibility that these mineralized centers occur as randomly as the map seems to indicate. Since most of these tectonic features are partially or completely hidden beneath younger rocks and by faulting, one part of the problem is defining them with some assurance beneath the present cover.

It is known that major structures, i.e. zones of weakness in the crustal basement, are apt to traverse rocks of several younger ages due to periodic re-occurrence of stresses along them on lines of weakness possibly established as early as oldest Precambrian time. If these deep seated features or riffs do, in effect, exert some controlling influence on igneous activity as many geologists postulate, due to higher heat flow along them, or by the tapping of deep crustal or upper mantle magmas when reactivated by major tectonism, then the definition of such zones and their various intersections could be of great importance in our exploration efforts.

Aeromagnetic data have provided one tool for measuring and delineating deep subsurface effects due to the change in magnetic susceptibility of the underlying rocks of igneous origin. However the problem of the masking of such deep effects by highly magnetic surface rocks (volcanics) and other local magnetic features often makes the interpretation of such subsurface magnetic trends very difficult.

Basically the purpose of this special project is to first establish, if possible, some correlation between lineations and intersections of deep igneous trends as may be discerned from aeromagnetic data with districts of major base metal mineralization generally thought of as having deep, hydrothermal

origins closely or directly related to intrusion. Secondly, and of most importance, to test these hypotheses by means of regional and detailed field work using every available exploration tool that might be helpful in uncovering an unknown district or orebody.

This is conceived as an ambitious and long range project that will require a good deal of work and time. It can best be implemented from this office, but it should be carried out with full knowledge of, and in cooperation with, the regional offices involved. Better still would be the assistance of an interested staff member from each regional office assigned to areas within the project to work with us from time to time. The nature of the problem is such that it can conveniently be executed in phases with an opportunity to fully evaluate the program prior to each succeeding phase.

Project Phases

Phase I has already been started and worked at for many months as a part of the normal geological and geophysical compilation procedure carried on by Bert Morrison for Utah and Nevada. It will include in depth literature search for geologic and geophysical information now in existence, the compiling of this information to convenient and uniform scales, the gathering of other background information such as mining districts, commodities, production, geology, and mineralogy. Although a great deal of work has already been accomplished, there yet remains a large quantity of information to be sifted and compiled.

Some extremely interesting and perhaps pertinent information has come to light in the last few years concerning sea floor spreading and continental drift as it effects world wide tectonism and igneous activity. Some study will be made to relate these new findings both geophysically and geologically to Basin and Range tectonics. Some understanding of possible stress directions and patterns in geologic time may be very helpful in interpreting regional magnetic and gravity data.

It is expected that after the compilation of base maps and surface geology that this phase will continue well beyond the initiation of Phase II.

Phase II. Under this phase we will undertake the operating upon of published aeromagnetic maps by computer techniques for the purpose of seeing trends and correlations that are not now plainly discernable. This work has also been initiated to the extent that computer programs have been written which will hopefully accomplish this purpose. However, all the actual computer work remains to be done and will require much machine time with its additional expense.

An aeromagnetic map covering all of Arizona will shortly be completed

by the University of Arizona for the participating companies and will soon be in our possession. About 36% of the state of Nevada is now covered by aeromagnetics and more will be done in the near future by the U. S. G. S. We have obtained all the aeromagnetics that we know about which are now available and have made composites at a reduced scale so that visual studies can be made of any lineations as well as studies of the relation of ore occurrences to the magnetic character. These studies indicate that almost every ore occurrence can be related to a particular magnetic anomaly but the converse is not true. (i. e. similar anomalies do not necessarily have companion ore deposits.) Also, several strong lineations are apparent but only broad generalities can be made regarding the relation of types and numbers of ore deposits to these. It is difficult to see possible correlations due to the great number of magnetic anomalies displayed on the composite maps. These composites are necessary for viewing large features. However, the computer can handle this problem quite easily.

J. R. Montgomery, geophysicist specializing in computer programming, has worked out several programs to help resolve the above stated problem as well as others. These programs are as follows:

1. Removal of regional gradient.
2. Wave-length filtering.
3. Fan filtering.
4. Horizontal derivatives.
5. Vertical derivatives.
6. Continuations.

An explanation of the meaning and purpose of these terms is included in the appendix of this memorandum by B. C. Morrison.

By using the above methods, we hope to be able to make correlations with and between geology, mine distribution, deep seated structures, and various geophysical methods. It is impossible to state just where these studies will lead. By being able to strip away individual magnetic features, it may be possible to make correlations which otherwise would be impossible to see.

Also under Phase II geologic investigators will put together a series of detailed paleotectonic maps showing conditions of sedimentation for geologic periods and epochs from Cambrian to Pliestocene time in an attempt to understand as completely as possible the geologic and tectonic history of the province. This line of research should also help provide factual data for interpreting basement structure. This will be done largely by compilation and study of published stratigraphic descriptions supplemented by field checks.

Phase III. This phase will consist of two areas of endeavor. (1) The

extension of basement trends outside the areas of published magnetics in the Basin and Range by means of our own aircraft capabilities, and (2) the evaluation of mineral occurrences and possible mineralized areas along the most promising of the revealed trends and intersections.

The first is straight forward and needs no elaboration, but will be costly in terms of aircraft and data reduction time. The second presents the greatest challenge of the entire project, and to it should be applied the integrated exploration team approach. Since this is such an important aspect of the problem it is well to define my concept of an integrated team approach. It is the approach used by this department in which the specialists in their various fields - geophysics, geology, and geochemistry - each having studied the data, sit down together and work out a reasonable exploration approach to a specific problem with a specific objective in mind. They decide what and when various tools can or should be employed, their cost, and what results can be expected from their use. The importance of the regional geologist's place on this team cannot be overstated. As with all teams some one must make the decisions that cannot be resolved through this procedure.

Tools available to us now that can be applied to mineral evaluation along trends by this team are: color aerial photography for geology and alteration studies, stream sediment and spring sediment geochemistry, heavy trace element analysis of rocks and of possible indicator minerals such as manganese, iron oxides, barite, flourite, etc., low level magnetics, gravity and I. P. surveys, detailed soil sampling, and conventional geologic reconnaissance from regional to detailed district mapping and mine examination. These are listed as extending downward from regional to district wide in scope and scale. In addition to the present tools available, we are counting on a possible tremendous contribution from the ELF EM system now under development which should be available in time for this phase of the project.

Phase III can be a continuing program extending over a long period of time at fairly high costs. However, it can also be appraised anew at almost any stage after sufficient time and effort has been spent along the first selected zones to provide enough data for subsequent evaluation. It is very probable that many new ideas and some new concepts will evolve during the course of the project. Several lines of exploration research will be followed up, and others will likely be suggested by results from initial studies. It is therefore unwise to pursue any extrapolation of the project beyond this point.

Implementation of the Project:

The execution of Phase I will not require much addition to the present staff. It will involve mostly a re-allocation of time by some staff members and the assigning of at least one full time draftsman, and perhaps two part-time library researchers to the project. This means the addition of one or two part-

time employees to our present organization.

Phase II will likewise require but small increase over present needs. The services of a part-time computer programmer and operator will be required to routinely process aeromagnetic and other data. Data processing costs will increase by 1000 to 2000 dollars per month while the computer is digesting the volumes of input now available. Procurement of some computer equipment such as a digitizer may become necessary as increased useage develops.

Additional geologic help also may be required for stratigraphic compilation, but this work can probably be accomplished by qualified summer help from university students. Additional field vehicles will be needed for field personnel during some of this work and particularly for Phase III.

Not until Phase III is started will any great demand be made above our normal division requirements. Even the assignment of the aircraft to this project for broad regional work will not materially increase our present operating costs. Any work carried out beyond this point will be directly related to normal divisional exploration efforts involving geological and geophysical personnel with supporting equipment and should be funded in the same manner as they are. It is difficult to anticipate accurately now what these total requirements will be, and this should await the evaluation of the two earlier phases before requests are made for additional permanent personnel.

Marvin P. Barnes

MPB:am
Attachment

MARVIN P. BARNES

APPENDIX

Removal of regional gradient.

A regional gradient is a surface, not necessarily a plane, on which the local anomalies appear. The result is that the true picture of the meaningful local anomalies is obscured by the contours of the regional gradient. The computer can remove this gradient by scanning all the data points for the entire area and then computing the regional gradient value of the data point under study. The regional can then be subtracted when the map is printed out. Practically, this can be done in two ways: (1) by the computer scanning all the points and computing the surface up to a pre-stated order equation, or (2) by the programmer stating the equation of the surface ahead of time and having the computer remove this surface.

Wave-length filtering.

Observation of a contoured aeromagnetic map will show that there are frequently at least three sizes of anomalies in a given large area. The local anomalies are the smallest, superimposed on larger anomalies. These larger anomalies are still of a size that several appear on the same map. These are in turn superimposed on the regional gradient. In such a case, programs can be written to remove (filter) all the small anomalies and leave the larger ones or remove the larger ones and leave the smaller ones. In the case of Nevada, this would make it possible to filter out almost all the smaller volcanic caused anomalies and leave only those caused by deeper, larger causes such as structural blocks. It is also possible to leave or emphasize only bull's eye anomalies resulting from stock like intrusives. Such an analysis is called wave-length filtering.

Fan filtering.

Frequently, very strong near surface caused lineations obscure more meaningful but much less obvious lineations or the clutter of many anomalies may completely hide a trend of anomalies. Such hidden trends can be emphasized by selecting a given direction and letting all other trends "fall off" as the angle away from this selected direction. In Nevada there is one very good example of the value of this type of filtering. Passing through Cortez is a NNW trend caused by basic dikes coalescing at depth (USGS). From the magnetics there is an indication of northeastwardly trending feature. By using fan filtering only those trends with a direction approaching northeast will be emphasized. All others will be attenuated according to their distance away from this direction.

Horizontal derivatives.

The first derivative is a mathematical term meaning the slope of a curve. The second derivative means the change in slope. The ordinary contour

map of aeromagnetics shows the amplitude of the magnetic field over the mapped area. The amplitude of a contoured map of the first derivative indicates the steepness of slopes of an anomaly and not the actual field strength of the anomaly. The second derivative shows by the amplitude the change of the steepness of slope. Some interpreters find each of these useful in bringing out subtle changes of slope which in turn can be used to define lineations and also be used to arrive at depth estimates.

Vertical derivatives.

If we are interested in the rate of change of intensity in respect to elevation, a first vertical derivative is used. In other words, we use it if we want to know how fast the anomaly will change if we move away from it or toward it. Deep anomalies tend to have a slower rate of change in the vertical direction than shallow ones. Second vertical derivatives can also be taken but are much harder to explain in that they are the rate of change of the slope (rate of change of the rate of change).

Continuations.

The usual aeromagnetic map is flown at only one flight level. Since magnetics are a force field, it is possible to calculate what the results would be either at a higher or lower flight level without actually doing the survey. When this is done mathematically, it is called a continuation. The downward continuation shows greater and greater detail until the depth of the causative mass is reached where it "explodes". This is one way of finding depth to the causative body. Upward continuations are used to see larger or deeper bodies, or for matching the results of various flight levels.