DEVELOPMENT OF NEW MULTIDISCIPLINARY TECHNIQUES FOR MINERAL EXPLORATION IN SEVERAL AREAS OF THE WESTERN IBERIAN PENINSULA.

Project ID: MA1M0032
Financiado con arreglo a: FP1-RAWMAT 3C

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Desde 1987-09-01 hasta 1990-05-31

Detalles del proyecto

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Objetivo


In mineral exploration, the multispectral approach involves the detection of an anomalous spectral response from surface rock, soil or vegetation which can be related to an orebody. Thus it is limited to the detection of near surface targets and has proved most successful in areas with little or no vegetation or where orebodies and the underlying geology produce significant alteration of surface soils and/or vegetation.

The mapping of structures and lineaments is essentially an extension of photogeological interpretation, where surface features are related to subsurface discontinuities, whose detection requires enhancement of gradients and discontinuities in surface reflectance. Traditionally photolineament detection has utilized stereomages derived from overlapping photographs, but LANDSAT and most other remote sensing systems produce limited overlap of imagery. The multispectral nature of much remotely sensed imagery and its digital form allow computer enhancement, combination and filtering of the data offering new and challenging opportunities to those engaged in geological exploration.

In many areas, particularly where superficial cover limits spectral resolution of bedrock, lineaments form the most coherent data derivable by remote sensing methods.

This study has demonstrated that remotely sensed data from LANDSAT thematic mapper (TM) and air photography, when combined with a good ground control of the structure, can be used to postulate a strong structural control to the mineralization of the La Codosera area, particularly the gold antimony and the uranium phosphate deposits. An understanding of the kinematics of these structures when linked to the mapping provided by LANDSAT imagery allows exploration models to be developed.

These models are built up by the integration of field based and remote sensing work in the following manner. Firstly, it is necessary to establish a clear correlation between sets of lineaments and fractures based on their directio nal, spatial and temporal relationships. Once this is established the LANDSAT imagery may be used to map specific lineaments, or zones of a particular pattern of lineaments. Only when the kinematics of these structure are understood can models be developed which relate the structural control of the various types of mineralization to specific locations, providing exploration targets. Thus remote sensing can provide a cheap and efficient way of mapping fracture systems and selecting targets for further
The gold exploration programme has involved geological mapping at various scales, soil and stream sediment geochemical surveys, and lithogeochemistry of specific formations. Within the anomalous gold zones, old workings have been reopened and specific targets have been trenched and diamond drilled. Los Algarbes represents one of the most interesting areas, where mapping at a scale of 1:5000, complemented by soil sampling, has indicated 3 major anomalies (La Portilla, Brena and Matasiete) with gold values higher than 0.3 parts per million in soils. Furthermore lithogeochemical studies of host lithologies from drill holes suggest that specific horizons where quartz veining is widespread carry significant gold (e.g. Lower Devonian Quartzite at 0.49 parts per million, iron rich sandstones at 0.013 parts per million).

The most significant gold prospects are located on a series of steep quartz veins trending 040 degrees, which show grades of up to 10 g/t, over a maximum thickness of 1.5 m, and are generally restricted to the Devonian black slates. These veins are developed on extension faults which postdate the main S1 cleavage. The veins show little visible wall rock alteration in the field and conform to the commonly described gold only veins with a restricted mineralogy of pyrite and arsenopyrite.

Geochemical analyses indicate that the auriferous veins of the La Codosera area resulted from the passage of dilute, carbon dioxide rich fluids at temperatures of 350°C and depths of approximately 10 km. The fluid contains appreciable amounts of methane (up to 20 mole %). The common association of mineralized veins within black slates suggest the reaction of fluid with carbonaceous wall rock plays an important role in gold precipitation. The dilute nature of the fluid and the connectivity of veins to the Badajoz Shear Zone suggests a shear zone origin for the fluid. Beta autoradiography indicates the gold is most likely lattice bound within the arsenopyrite structure.

Digital classification of LANDSAT thematic mapper (TM) data has discriminated 2 spectrally contrasting soils within the contact aureole of the Alburquerque Batholith. The resulting classification delimits the metamorphic aureole of the granite. Extending this classification over a wider area outlines an area, west of La Codosera, where soils, derived from Devonian slates, show a similar spectral classification to those found within the contact aureole of the granite. Comparison of the TM classification with aeroradiometric data, using a geographical information system (GIS) system, showed the coincidence of a moderate K(e) anomaly in the same sector as the anomalous soil classification west of La Codosera. These data in association with the observed gravity low and the presence of spotted slates over the same area strongly suggest the presence of a granite cupola at depth.

Using the LANDSAT data, combined with the ground structure, air photograph interpretation and gravity data, a clear picture of the fracture system has emerged. 3 major sets of lineaments trend 045 degrees, 135 degrees and north south, and these correlate with extensional fractures, including those at known mineral prospects. In addition LANDSAT lineaments correlate with known faults in many parts of the area, thus providing a useful dataset with which to augment the regional structural studies.

Known uranium and phosphate mineralization is largely confined to large 045 degree fractures, with evidence that these veins form in arrays along 030 degree and 065 degree lineaments, many of which may be identified from LANDSAT. Tin, tungsten and lithium mineralization mainly occurs along both 135 degree and 045 degree fractures in the aureole of the Alburquerque granite, particularly where lineaments of these trends dominate.

Several east west lineaments cut the Central Ridge and appear to correspond with known gold prospects of this trend. In the Southern Ridge, where the bulk of the prospects are located on quartz veins with Devonian quartzites and slates, a clear relationship between the mineralization and LANDSAT lineament pattern has been established.

The multidisciplinary nature of the work has generated a wide range of different spatial data, which can best be integrated and compared using a geographical information system. Geological maps, gravity, aeroradiometric data and LANDSAT TM classification were analyzed. The resulting maps illustrate the great potential of GIS within exploration programmes.

Not only can different datasets be superimposed quickly and accurately, but these data can be readily updated in response to further exploration and drilling. This has been particularly valuable in the intensively investigated area to the west of La Codosera. Selected anomalies can be displayed, including moderate K(e) values, the TM contact metamorphic soils and the Bouguer gravity contours. The resulting coincidence of the negative gravity anomaly, moderate K radiation and TM classified contact soils, are suggestive of an intrusive body at depth.

In the Los Algarbes area, the main prospects lie on steep north south to north east south west veins developed as extensional fractures with some left lateral reactivation, sited at the terminations of the larger north east south west faults. These major fracture zones (lineaments) provide connectivity between the shear zone and the Southern Ridge of Palaeozoic rocks which host the main gold and antimony mineralization.

Based on detailed observation of the structural setting of veins and investigation of their geochemistry and fluid characteristics, a number of prospective settings have been recognized. The gold bearing veins generally occupy north south to north east west trending extension fractures developed at the terminations or offsets of major north west south east trending faults or where dilation was produced at intersections of these with their conjugate (north east south west) set. The north west south east faults have a right lateral component of slip and form part of an extensive bookshelf of domino system linking the Southern Ridge to the Badajoz Shear Zone. Maximum dilation will occur where the domino faults change orientation or have large displacement. It is significant that the main area of old gold workings at Los Algarbes occurs at the northwestern end of the main change in orientation of the domino faults and that the San Antonio antimony mine occurs at the north west extension of a large displacement fault. Using the known structural controls, the lineament map provides a basis from which to identify new target areas which show abundant north south to north east south west fracturing in a similar structural setting.

The current drilling programme at Los Algarbes is within 1 of the proposed target areas and confirms that the gold is associated with north north east trending extension veins, possibly developed as pinnates to a north east south west fault, conjugate to the main north west south east feeder faults. The spatial association of the Los Algarbes area with a gravity low, anomalous K radiation and thematic mapper (TM) signatures characteristic of known contact metamorphic soils suggest the presence of a buried pluton. The fluid chemistry of auriferous veins, however, supports a shear zone source with the methane
content possibly reflecting interaction with carbonaceous shales. In addition the presence of auriferous quartz veins is noted in areas such as the Central Ridge, which are not underlain by granites. Thus, the role of the buried plutons may be to act as stress concentrators, promoting fracturing, or they may control and enhance pore fluid circulation.

This study has demonstrated a strong structural control to the mineralization of the La Codosera area. An understanding of the kinematics of these structures and the nature of the mineralizing fluid then allows exploration models to be developed. Remotely sensed data from LANDSAT TM, when combined with good ground control can then be used to systematically define prospective targets.

The mapping of geological structures and lineaments is essentially an extension of photogeological interpretation, where surface features are related to subsurface discontinuities, whose detection requires enhancement of gradients and discontinuities in surface reflectance. Traditionally photolineament detection has utilized stereomages derived from overlapping photographs, but LANDSAT, and most other remote sensing systems, produce limited overlap of imagery. The multispectral nature of much remotely sensed imagery and its digital form allow computer enhancement, combination and filtering of the data offering new and challenging opportunities to those engaged in geological exploration.

In many areas, particularly where superficial cover limits spectral resolution of bedrock, lineaments form the most coherent data derivable by remote sensing methods.

This study has demonstrated that remotely sensed data from LANDSAT thematic mapper (TM) and air photography can be used to map the fracture pattern in the Mina Fe area. These fractures exert a structural control on the mineralization, as at Mina Fe itself where mineralization occurs along small faults. The kinematics of these structures involves reactivation under at least 2 different stress systems, but uranium mineralization can not be linked to particular phases of movement. Thus mapping of lineaments from LANDSAT, may be of use in following out local anomalies.

Zones of swarming of north east south west lineaments provide some useful data on the location of prospective areas, especially if accompanied by high fracture density. Given the small scale of some local anomalies, it may be that air photography provides a more suitable tool for this sort of exploration.

To develop structural models further would require detailed integration of field based and remote sensing work in the following manner. Firstly, it is necessary to establish local uranium anomalies and link these to particular faults. Then these could be linked to particular lineaments based on their directional, spatial and temporal relationships. Once this is established the LANDSAT imagery and air photographs may be used to map specific lineaments or zones of a particular pattern of lineaments. Only when the kinematics of these structures are understood can models be developed which relate the structural control of the various types of mineralization to specific locations, providing exploration targets.

The Fe deposit is the largest known breccia hosted uranium deposit in the Hercynian basement of the Iberian Meseta. All of the deposits of this type show similar geological characteristics and a common model is required to explain their origin. As far as the Fe mine is concerned, mineralogical, fluid inclusion and stable isotope data on the Fe mineralization suggest a model for ore formation generally similar to those proposed for the Front Range and Midnite deposits, particularly the former. Oxygen and carbonate analysis demonstrate that the hydrothermal fluid was derived from meteoric water that was heated and underwent isotopic data show that the early fluid was highly evolved whereas latter fluid was less evolved and probably resulted from mixing of hydrothermal fluid with shallow groundwater. Carbon isotope data indicate that carbon in the carbonate gangue minerals was derived from carbonates and graphitoid in the metasediments.

Sulphur isotope data are compatible with the sulphur having been derived from biogenic pyrite in the metasediments and the minor amounts of pyrite in the late stage mineralization have extremely low sulphur-34 values, suggesting that biogenic reduction of sulphate to hydrogen sulphide took place on the subsurface cavities that were the sites of last stage mineral deposition.

Based on current geological knowledge of the Fe deposit and the stable isotope data presented above, the most appropriate model for the origin of the deposit is that of a hydrothermal system operating in response to Alpine tectonic activity in the lower to middle Tertiary. Extensive, steeply dipping faults permitted the deep penetration of meteoric water which became heated and reacted with the metasedimentary rocks. Uranium, and other components of the mineralization, were derived by leaching from the metasediments. The hydrothermal system may have been driven by seismic pumping processes. The heat source for the Fe hydrothermal system may have resulted from conversion of mechanical energy into heat during tectonic deformation in an analogous way to that which takes place in major shear zones. In the vicinity of the Fe mine, there are numerous and important faults and fractures related to shearing that, although not comparable in size with the shear zones produced at much deeper levels at the end of the Palaeozoic could be the result of deformation in the Hercynian basement by the Alpine orogeny. The heat generated would then have been dissipated towards the surface by fluids that were expelled through fracture and breccia systems following the collapse of the dilatant zones. Alternatively, the heat source could have been related to crustal thinning during development of the Ciudad Rodrigo basin.

LANDSAT satellite imagery of the Nisa area has allowed a structural approach to lineament analysis. Lineament data have scalar, directional and spatial information, and these features require different, but interdependent, forms of analysis. Structurally controlled processing consists of a package of computer programs to facilitate the manipulation and display of the directional and spatial attributes of lineament data. These allow plotting, georeferencing, directional filtering, etc of lineaments and the generation of rose diagrams and maps.

The distribution of lineaments mapped from various enhancements of thematic mapper (TM) data in the Nisa area can be divided into 3 clearly defined sets trending 060 degrees, 130 degrees and north south. The north south set correlates well with extensional fractures and quartz veins, including those at known mineral prospect within the granite. Lineament analysis provides a useful dataset to augment the regional structural studies. In order to convert these data into viable exploration models it is necessary to understand and relate the nature and kinematics of the fracture control to the mineralization.

The main new result to come from this work concerns the possible significance of major north west south east lineaments. These fractures may control the fluid flow and mineralization in the granite. Precipitation is associated with north south extension fractures locating the vein style mineralization. It may be significant that such structures were not recognised in the Alburquerque part of the batholith, which contains significantly less uranium mineralization.
The fundamental aim of the project is to develop new mineral exploration strategies applicable within the Iberian Peninsula for a variety of elements, including tin, tungsten, niobium, tantalum, lithium, antimony, gold and uranium. The main findings in the La Codosera area involve the following:

tectonic setting (a Precambrian sequence overlain unconformably by alternations of quartzite and slates ranging from Lower Ordovician to Devonian in age);
gold exploration (the gold exploration programme involved geological mapping at various scales, soil and stream sediment geochemical surveys and lithogeochemistry of specific formations);
geochemistry (geochemistry analyses indicate that the auriferous veins of the area resulted from the passage of dilute, carbon dioxide rich fluids at temperatures of 350 °C and depths of approximately 10 Km);
gravity (the gravity survey has demonstrated that the major source of density variation in the upper crust can be attributed to granites such as the Alburquerque Batholith);
landsat thematic mapper (TM) (digital classification of Landsat TM data has discriminated 2 spectrally contrasting soils within the contact aureole of the Alburquerque Batholith);
lineament analysis (3 major sets of lineaments trend 045 degrees, 135 degrees and north south and these correlate with extensional fractures, including those at known mineral prospects);
use of a geographical information system (GIS) to integrate exploration (the wide range of different spatial data, can best be integrated and compared using GIS);
structural control of gold mineralization (the major fracture zones (lineaments) provide connectivity between the shear zone and the Southern Ridge of Palaeozoic rocks which host the main gold/antimony mineralization).

Further work in Spain and Portugal involve the mapping of fracture zones in the inn mine area (the fractures effect a structural control on mineralization) and the potential for gold mineralization in the Nisa area of Portugal.

The aim of the project was the development of exploration guidelines for mineralization, in particular gold, within the central and west Iberian peninsula. Research focused on regional structural studies, Landsat interpretation and geochemical analysis of the fluids deemed responsible for the mineralization.

In the Los Algarbes area, the main prospects lie on steep north south to northeast southwest veins developed as extensional fractures with some left lateral reactivation, sited at the terminations of the larger northeast southwest faults. These major fracture zones (lineaments) provide connectivity between the shear zone and the Southern Ridge of Palaeozoic rocks which host the main gold/antimony mineralization.

Based on detailed observation of the structural setting of veins and investigation of their geochemistry and fluid characteristics, a number of prospective settings have been recognised.

The current drilling programme at Los Algarbes is within 1 of the proposed target areas and confirms that the gold is associated with north northeast trending extension veins, possibly developed as pinnates to a northeast southwest fault, conjugate to the main northwest southeast feeder faults.

The spatial association of the Los Algarbes area with a gravity low, anomalous radiation and thematic mapper (TM) signatures characteristic of known contact metamorphic soils suggest the presence of a buried pluton.

This study has demonstrated a strong structural control to the mineralization of the La Codosera area. An understanding of the kinematics of these structures and the nature of the mineralizing fluid then allows exploration models to be developed. Remotely sensed data from Landsat Tm, when combined with a good ground control can then be used to systematically define prospective targets.

IN THE FRAMEWORK OF THIS JOINT PROJECT, THE PARTICIPANTS WILL PERFORM:
1. REMOTE SENSING INTERPRETATION TO IDENTIFY DILATION ZONES IN MAJOR LINEAMENTS AND TO DELINEATE METAMORPHIC AUREOLES AS A DIRECT GUIDE FOR MINERALIZATION. TECHNIQUES WILL INCLUDE INTERPRETATION OF TM AND SPOT IMAGERY (IGME, SOUTHAMPTON, BELFAST, AVEIRO).
2. LITHOGEOCHEMICAL STUDIES AND CONTROL OF VARIOUS TYPES OF STRATABOUND MINERALIZATIONS (W, AU, SB, U) IN METAMORPHIC PALEOZOIC ROCKS AND IN THE SCHIST-GRAYWAKE COMPLEX AND DEVELOPMENT OF MULTIDISCIPLINARY APPROACH FOR THEIR EXPLORATION (SOUTHAMPTON, SALAMANCA, IGME, ENUSA, ENU).
3. ORGANIC GEOCHEMISTRY CONTROLLING METAL CONCENTRATIONS (ESPECIALLY AU, U) (SOUTHAMPTON).
4. MINERAL PARAGENESIS INVESTIGATIONS INCLUDING MINERALOGICAL, PETROGRAPHICAL, GEOCHEMICAL AND FLUID INCLUSIONS STUDIES (SOUTHAMPTON, SALAMANCA, IGME).
5. HEAVY MINERAL CONCENTRATES STUDIES FOR IDENTIFYING POTENTIAL SOURCE ROCKS (IGME, SALAMANCA, SOUTHAMPTON).

THE MAIN AIM OF THIS JOINT PROJECT IS DEVELOPING METHODOLOGIES FOR LOCATING TARGETS IN FUTURE EXPLORATION.

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Última actualización el 1994-01-23
Obtenido el 2019-05-21

Enlace permanente: https://cordis.europa.eu/project/rcn/11480_en.html
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