D-39 AIRBORNE GRAVITY AND MAGNETICS INTERPRETATION OF THE PUTUMAYO AND UPPER MAGDALENA VALLEY, COLOMBIA

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Summary

Exploration in rugged topography continues to be a very difficult, costly, and oftentimes hazardous undertaking. Airborne gravity and magnetics has proven itself to be a useful geophysical technique for rapid and cost effective exploration. This is particularly the case when ground access is limited owing to natural barriers, topography, and foliage. Recent data acquired in an airborne gravity and magnetics survey program in southern Colombia provide the basis for interpretation of the structural features and exploration potential of the area.

Introduction

The study area covers approximately 40,000 square km, with dimensions of 500 km long and 80 km wide (see figure 1). The survey extends from the Putumayo River along the Colombian/Ecuador border northwards along the Magdalena Valley beyond the town of Neiva. The geography of the area is typical of the South American Andean Cordillera; mountains running southwest to northeast form natural borders along the west and northeast. The mountain ranges rise sharply from the valleys, foothills and low-lying southern plains (1,600 ft amsl) to elevations of several thousand feet (in excess of 15,000 ft amsl). The Magdalena Valley and Putumayo area are physiographically distinct and are separated by a broad ridge, which runs perpendicular to the axis of the valleys and mountains, representing the southernmost expression of the Cordillera Oriental (Eastern Cordillera).

Approximately 14,000 km of airborne gravity and magnetics data were acquired at a constant barometric altitude of 10,000 amsl. The data were acquired in less than 60 days in extremely uncooperative weather. Typically, only a narrow time window was available for acquisition each day. The data were acquired using a Cessna Caravan survey aircraft, a ZLS-modified LaCoste & Romberg dynamic gravity meter, state-of-the-art GPS technology, and a cesium vapor magnetometer with active compensation (see figure 2). Despite the weather, reflights were kept to a minimum, thought the use of sophisticated data processing methods, which accurately model the aircraft movements in post-processing. The processed products yielded maps of topography (derived from available data, plus the radar altimeter profile), free air gravity anomaly, terrain-corrected Bouguer gravity anomaly, isostatic gravity anomaly, and total magnetic anomaly.

Project Objectives and Methodology

The objective of the interpretation was to define the principal structural elements and the distribution of sedimentary basins across the study area. The gradient information content in the gravity and magnetic data is structurally definitive and can be used to identify the location and orientation of the main intrasedimentary faults (thrust, wrench and normal) and basement fault block boundaries. The residualized gravity data were inverted and modeled to provide information about the extent and thickness of the main sedimentary basins. The magnetic data were used to confirm the depth and structure of the magnetic basement, which in the study area is assumed to coincide with the top of crystalline basement.

The interpretation methodology involved: 1) building a series of geological profiles which contain all of the known and expected lithological and structural control, 2) calculation of the theoretical gravity and magnetic effects of the geological models, 3) comparison of these effects with the observed fields, 4) design and implementation of potential fields filters to remove regional effects such as long wavelength terrain “noise” and isostatic signals, and to enhance the measured effects of the local geology, 5) design and implementation of Euler deconvolution operators for 2D and 3D magnetic depth calculation, and 6) construction and inversion modeling of the entire gravity field constrained along a number of key profiles.

Regionally, the areas can be divided into two distinct oil-bearing provinces: the Neiva sub-basin (south of the town of Neiva) and the Putumayo foothills (north of the Ecuador border), presently separated by the Eastern Cordillera ridge but probably joined during pre-Tertiary times. The Upper Magdalena Basin south of Neiva is bounded by thrust faults verging east and west, which are expressions of two different compressional events. Several other thrust faults (inverted) can be mapped within the basement, defining topographic highs that separate narrow, deep-seated sub-basins many of them covered by thin volcanic sequences, but now unveiled through the interpretation of gravity and magnetics data. The Putumayo foothills represent a promising area for underthrust plays, covered by thick igneous sequences.

In general terms, basement anisotropy is expected to exert a fundamental influence on the geometry of a superimposed compressional fault system. It is likely that the major thrust faults in this area may overlay or coincide with an earlier sequence of normal faults. Given sufficient geological control it is possible to distinguish thin-skinned tectonic elements from deep-seated, underlying, normally faulted basement structures.

Examples

In this study, several structural provinces have been interpreted from changes in character of the magnetic field. The highest frequency magnetic anomalies are mapped in the NW and NE (areas A and C in Figure 3). These areas are comprised of mainly linear and sub-linear elements generally striking NE to SW. The majority of these short wavelength anomalies have close correlation with terrain, suggesting basement is likely to be at or near the surface.

The RTP map has clarified the nature and geometry of the central thrust zone –area C where several discrete upfaulted basement blocks can be expected. Anomalies along this broad zone are distinctly positive in the reduced to pole field, are linear, and appear to broaden progressively from northeast to southwest. The high amplitude of these anomalies (100nT to 150 nT) in combination with the increase in wavelength suggests that they represent magnetic basement which is highly faulted and which deepens southwards. In addition, a number of cross-faults can be observed.

The area of deep basement in the south is clearly evident from the broadening of the anomalies in this region. A major thrust fault boundary is interpreted to separate deep basement in the Putumayo Basin from the relatively shallow and tectonized basement ridge in the west and northwest.

A deep elongated basin is clearly identified in the north of the area from the negative linear magnetic anomaly that is mapped along the axis of the valley. This feature is correlated with a series of negative gravity anomalies evident in the residual gravity field. The basin appears to be fault bounded on all sides. Pease refer to figure 4 for the structural summary.

Although the RTP field along the northern margin is strongly negative, the associated high frequency high relief appearance in this area suggests that the basement is shallow but comprised of relatively less magnetic rocks as opposed to a deepening of the magnetic basement.

Conclusions

The airborne gravity and magnetic data successfully resolved a number of deep sedimentary basins and regional fault structures. Prospective basins have been identified and are currently undergoing additional exploration follow-up. A series of interconnected, narrow fault bounded sedimentary basins is evidenced from the gravity and magnetic data. This area is also transacted by a number of large faults, which are clearly visible in both the gravity and the magnetics data, which offset the resolved basins. These faults are parallel or strike close to many of the existing seismic lines that have been shot in this area, and are difficult to infer from the seismic data alone.

Present exploration of the region focuses on several areas, which have been cost effectively, high-graded with the airborne gravity and magnetic data. Renewal of interest is demonstrated by the present unavailability of open lease blocks in the region, indicating the likelihood that numerous wells will be drilled in the near future.

Fig 1 Location of study Area (Shown in yellow)

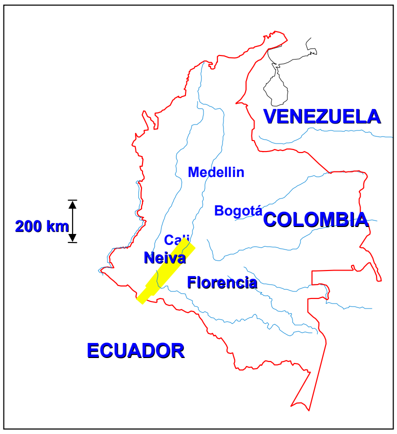

Fig 2 Equipment Installation

Fig 3 Structural Provinces

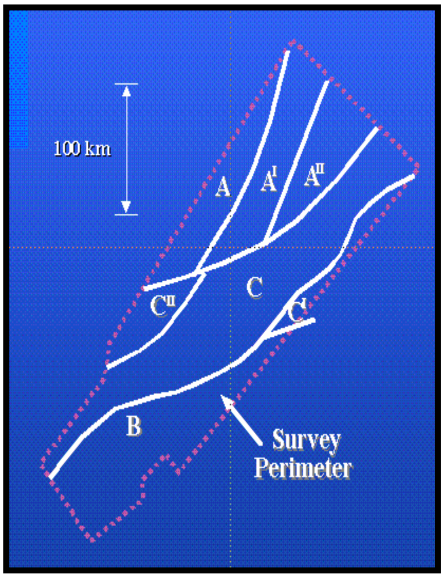

Fig 4 Structural Summary