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Will the compass go the way of the dinosaur in Traverse lay out for regional exploration programmes?

¿Le pasará a la brújula como al dinosaurio en las descripciones geológicas de los programas de exploración regional?

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Abstract

An investigation of the methodologies of using compass laid-out and GPSr laid-out traverses for regional exploration programmes is investigated in this work. Both advantages and disadvantages of both methods are discussed and a case study is presented. We conclude that in all likelihood that the compass will become obsolete in regional exploration programmes.

Key words: Compass, handheld GPS station, regional exploration.

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1. INTRODUCTION

The *Instituto Geológico e Mineiro* (IGM) and some precursor institutions, namely the *Direcção Geral de Geologia e Minas*, are closely linked to a rich history of mineral exploration both nationally and in the former colonies.

Generally, the start of regional exploration programmes for metallic minerals involves the collection of stream sediment, rock chip, water and soil samples where previous geochemical data is not available. This may well be linked to geophysical data gathering depending on the terrain and nature of ore bodies in question (e.g. Iberian Pyrite Belt).

The location of stream sediment, rock and water samples is largely dictated by existing topographic and geomorphologic terrain features. However, soil samples can be collected anywhere where a reasonable soil profile is developed in regions of poor outcrop. Soil sampling has, therefore, to be carried out in a systematic pattern so as to test the area in question as well as test the underlying lithologies. Therefore, the best way to undertake this is to carry out soil sampling traverses, in single lines, to test potential areas generally or grids to test areas in more detail.

This paper briefly outlines the methodology used in general regional exploration with compass laid out traverses or grids and contrasts that same methodology with using GPS receiver that makes use of the U.S. Global Positioning System to lay out traverses or grids. The advantages and disadvantages of each method are discussed, and finally a case study is presented.

2. WHAT IS GPS?

The Global Positioning System (GPS) is a Global Navigation Satellite System (GNSS) made up of a network of 24 satellites placed into an approximately 20 000 m-high orbit above the earth by the U.S. Department of Defence. GPS was originally intended for military applications, but in the 1980's, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS (www.garmin.com/aboutGPS/).

Today there are two GNSS's in operation; the previously referred to GPS (U.S. Global Positioning System) and the Russian GLONASS (GLObal NAvigation Satellite System), both of which are military systems. These systems are constantly being upgraded to meet higher standards of reliability. A third GNSS, a civil system named GALILEO, is currently being developed in Europe to specifically provide a higher standard of integrity and reliability, required to ensure the safety of lives during transport by air, land and sea. This system is scheduled to come on line between 2006-2008 (http://europa.eu.int/comm/dgs/energy_transport/galileo/index_en.htm).

2.1 How it works

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers (GPSr's) take this information and use triangulation to calculate the user's exact location. Essentially, the GPSr compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPSr how far away the satellite is. With distance measurements from more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

A GPSr must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more (www.garmin.com/aboutGPS/).

2.2 How accurate is GPS?

GPSrs are extremely accurate, thanks to their parallel multi-channel design. The now common 12 parallel channel receivers are quick to lock onto satellites when first turned on, and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPSr's. On average, the available GPSr's are accurate to within 15 meters.

Satellite-Based Augmentation Systems

Newer GPSr models with Satellite-Based Augmentation Systems (SBAS) capability can improve accuracy to less than three meters on average. While the GNSS networks are being developed to achieve maximum performance, SBAS have been established to provide improved accuracy, providing differential signal corrections for GPS and GLONASS transmissions.

SBAS are networks of ground relay stations and geostatic satellites designed to receive satellite navigation signals and transmit corrected time and distance measurements that greatly improve accuracy. Observation and relay stations have been set at known positions all over the world, while their geostatic satellites continuously maintain a fixed position above the Earth. Using these known values for distance, SBAS corrects satellite navigation signals for atmospheric delays, incorrect satellite positioning and poor geometry, sometimes caused by inline or close alignment of satellites, increasing accuracy in specific regions. Using the same signal frequencies as satellite navigation, SBAS-enabled receivers are inter-compatible.

Three augmentation systems are currently in varying stages of operation and development covering North America (WAAS - Wide Area Augmentation System), Europe (EGNOS - European Geostationary Navigation Overlay System) and Asia (MSAS - Multifunctional Transport Satellite-based Augmentation System). The incredibly accurate positioning capabilities of SBAS are already being used in mining, agriculture, development and many other industries as well as hiking, boating, hunting, travel and an expanse of other leisure and business activities in North America. The European system, EGNOS, is scheduled for full operation in 2004 and represents the first step toward Europe's GALILEO global satellite navigation system. MSAS is scheduled for full operation in 2005 and will expand safety and air-traffic capacity in the Asia pacific regions (http://www.thalesnavigation.com/en/products/aboutgps/augmentation.asp).

Differential Global Positioning System

Users can also get better accuracy with Differential Global Positioning System (DGPS), which is a system designed to improve the accuracy of Global Navigation Satellite Systems by measuring infinitesimal changes in variables to provide satellite positioning corrections.

Two or more receivers observe the same set of satellites, taking similar measurements that produce similar errors when positioned closely together. A reference receiver, placed at a known location, calculates its theoretical position and compares it to the measurements provided by the navigation satellite signals. The difference between the two values reveals the measurement error. The reference receiver then transmits a corrected signal to any number of receivers at unknown positions within the area covered by the DGPS. Accuracy of global satellite positioning is thereby increased from 15 meters to within a few meters. This technique compensates for errors in the satellite navigation system itself but may not always correct errors caused by the local environment when satellite navigation signals are reflected off of tall buildings or nearby mountains, creating multi-path signals. The accuracy of DGPS decreases with asynchronous measurement caused by spatial and temporal error decorelation when the system receivers are set at greater distances apart.

The most sophisticated DGPS techniques can increase positioning accuracy to within a few millimeters. Raw measurements recorded by the reference receiver and one or more roving receivers can be processed using specially designed software that calculates the errors. The corrections may then be transmitted in real time or after the fact (post-processing). By applying the corrections and recalculating the position, accuracy from within several meters to within a few millimeters is achieved, depending on the specific methodology used and the quality of the real-time data link (http://www.thalesnavigation.com/en/products/aboutgps/dgps.asp).

3. METHODOLOGY FOR REGIONAL EXPLORATION

Generally, any exploration programme starts with a target area and very clear objectives for that area as well as a reasonably good understanding of the geological conditions of the area.

Once these parameters are known and target areas delimited, the best way to test the area in question is to undertake soil sampling traverses over large distances, with widely spaced samples (e.g. 100 m), to test larger areas or grids to test in greater detail a smaller area.

Traverses or grids are initially sited given the local geological and geomorphological conditions of the terrain and are initially plotted on a map. These lines have to subsequently be transferred from the map into the field.

For the purpose of discussion and methodology, we will no longer distinguish between traverses and grids since the one is a composite of the other, and the methodology of carrying out a traverse or a grid in the field is simply that one has more traverses at right angles to each other.

3.1. Traditional compass methodology

The start point of the traverse has to be found in the field using map data coupled with visual characteristics of the terrain. Once this point is found, set up of a sighting compass, preferably tripod-mounted for stability, can now begin. Azimuth of traverse is taken with the compass and traverse lay out can begin. From the start point a member of the team will walk out a measured distance and plant a sighting staff. The placement of this sighting staff is determined by the compass operator that will direct the direction the traverse given the deviation to the left or right of the sighted azimuth. A second member of the team with a second sighting staff will then leapfrog the first sighting staff and line the second staff up at a measured distance until the desired second point of sampling / measurement is reached. This leapfrogging action continues until the whole traverse is marked in the field. In the case of grids, the use of an optical square is required to sight traverses at right angles to each other. If this is not available, then field personnel must resort to the Pythagorean Theorem to resolve traverse lines.

This method works well in flat and clear terrain but problems arise in hilly, heavily vegetated or woody terrain. In the case of hilly terrain, measurement between points or sighting staffs has to be carried out in a line projected above the terrain on a flat surface and not parallel to terrain dip so that accurate distances are measured. In terrain with dense vegetation, the vegetation has to be cut so that visual contact can be maintained between compass and successive sighting staffs. However, in terrains where obstacles are present in the line of traverse, the traverse line has to be deviated to the left or to the right of the obstacle and then brought back to the original line (Fig.1).

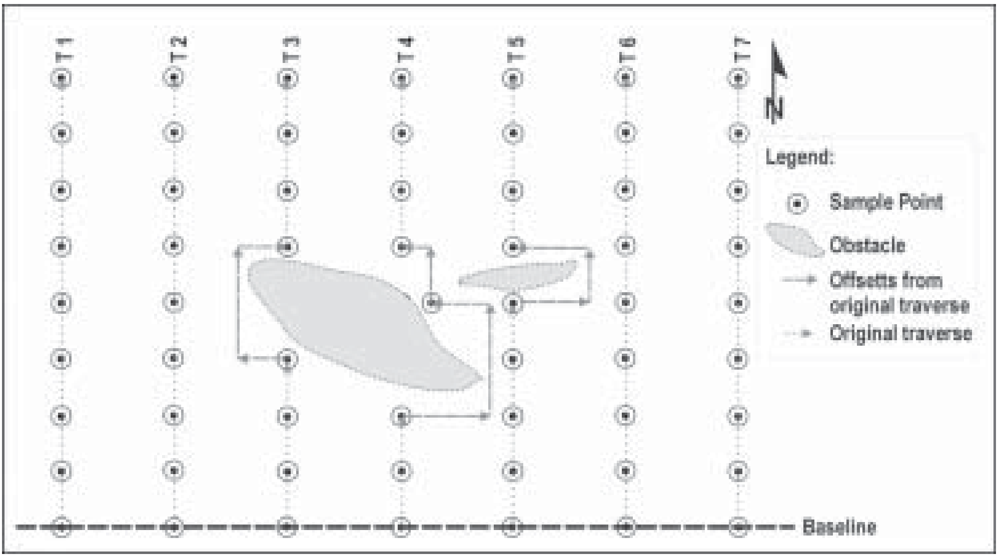

Fig. 1. Hypothetical soil sample grid lay out. Shown in grey are the offsets characteristics of a conventional compass-laid grid pattern to overcome line-of-sight obstacles.

Advantages of the compass method:

1. Relative accuracy in flat, obstacle-free terrains with easily recognisable landmarks;
2. Ease of use.

Disadvantages of this method:

1. The set up of the starting point in the field can be out by as much as a 100 m due to comparison of map and terrains geomorphology;
2. Time consuming and expensive;
3. Labour intensive since one member is always needed to sight the compass and at least two to leapfrog each other with sighting staffs;
4. Errors in measurement between sampling points can be induced due to uneven terrain;
5. Poor accuracy in flat, obstacle-free terrains with no easily recognisable landmarks;
6. Measurements using tape measures have to be carried out in short intervals to prevent tapes becoming concave and inducing in measurement errors;
7. Equipment intensive (compass, tripod, sighting staffs, tape measure / s, machetes + sampling equipment).

3.2 **GPSr methodology-**

In this section the use of handheld GPS stations with *waypoint* and *navigate* capabilities are investigated. These types of GPS stations / receivers are ideal for traverse lay out in the field.

This methodology needs the same careful planning and selection of target areas as the previous method. When traverses are plotted on a map, the starting point and end point coordinates of these must be obtained for every traverse to be carried out.

Once in the field, the starting point of the traverse can be accurately determined using the GPS station by walking the general area of the start point until map-extracted coordinates and field obtained coordinates match, or navigating to the start point from a random, close by point. Once the starting point is found, the GPS can be programmed to follow a specific route that will follow the traverse line. This is done by entering the end point coordinates and selecting the navigate function on the GPS station. The GPS will compute distance and direction based on the two sets of start and end coordinates. Measurement is taken as a projected horizontal line above the terrain, and distances are simply read off as one walks the traverse. The GPS will warn of deviations from the intended traverse and corrections can be carried out systematically in the field with little trouble. With the use of the GPS it is far easier to overcome obstacles some of which may be walked over or simply contoured since there is no need to keep the starting or intermediate points in visual contact.

Advantages of the GPSr method:

1. Ease of use;
2. Fast and cheap;
3. Relatively precise depending on map scale at which the work is carried out;
4. Not labour intensive;
5. Ease of use in the way of obstacles;
6. Not equipment intensive; elimination of the compass, tripod, sighting staffs and tape measures;

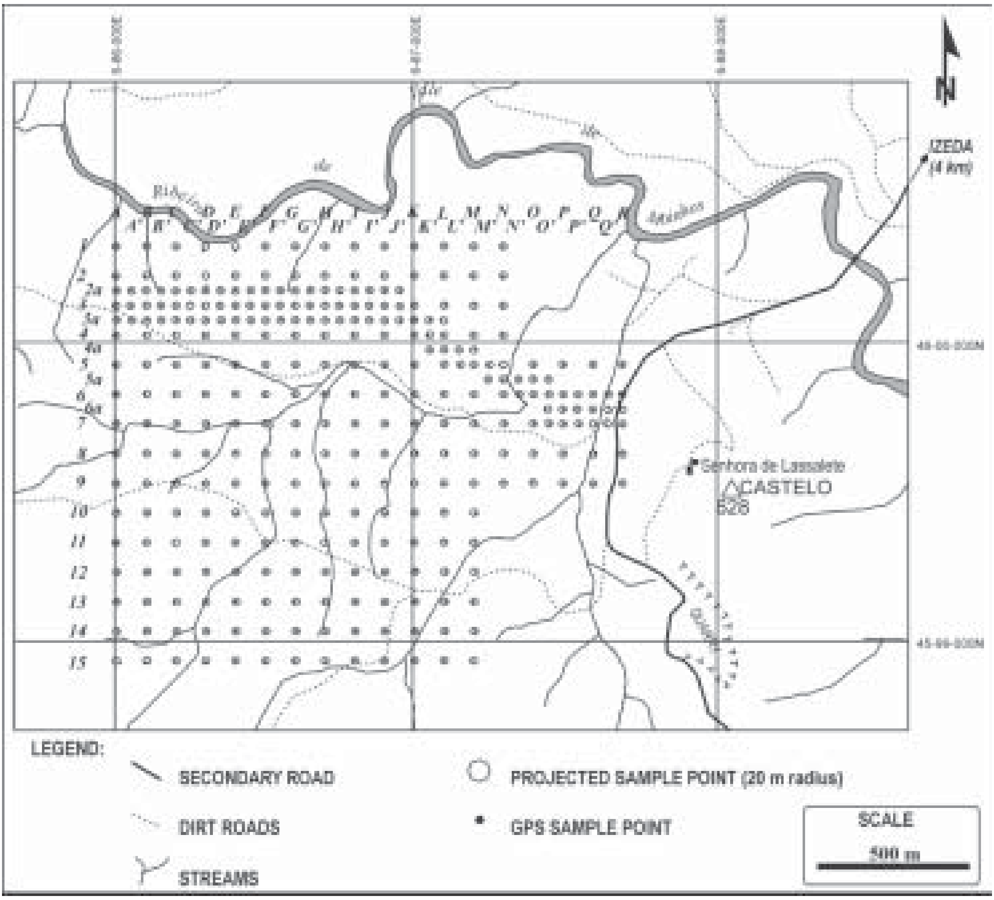

Fig. 2. Simplified excerpt of the 1:25000 Military Topographic sheet 79 (Morais) showing the soil sampling grid undertaken south of Izeda in the Morais Massif. Shown is the close correlation obtained between projected sampling points and GPS obtained sampling point. Deviations from this correlation are observed occasionally due to natural geological and geomorphological occurrences.

7. Very accurate to determine the starting point of the traverse;
8. Ease of integration in GIS software packages.

Disadvantages of the GPSr method:

1. Large trees with extensive foliage will hinder communication between the GPS station and satellites;
2. Relative precision of GPS stations can induce in errors less than 15 m. However, on a 1:25000 map scale even this error is insignificant. This error can be substantially reduced if two GPS stations are used in conjunction, one stationary and the other mobile (Differential GPS).

4. A CASE STUDY

During the course of a regional exploration programme for gold associated with platinoids in the *Trás-os-Montes* region (de Oliveira, 2003), more specifically 4 km S of *Izeda* in the Intermediate Allochthonous Ophiolitic Complex (Pereira *et al.*, 1998; 2000), of the *Morais Massif* (NE Portugal), a 100x100 m soil sampling grid was set up using a handheld GPS station. In the northern part of this grid, this distance was halved (Fig. 2) to obtain greater resolution near thrust planes.

Here the terrain is gently undulating in the north and hilly in the south of the grid and characterised by dense 1 to 2 m high brush throughout as well as clumps of trees in the north.

A total of 290 samples were collected in this region. Total time of collection, over 24500 m of traverses, totalled 12.5 working days (8 working hours / day) using a handheld GPS station. In contrast, it is estimated that using compass laid out traverses, each 1500 m traverse would take 5 working days to complete given the terrain and vegetation cover characteristics. Therefore, the 24500 m of traverses laid out in the *Izeda* area would have taken an estimated 82 working days given no setbacks, i.e. a time saving of 85% has been obtained by using the handheld GPS station. Furthermore, the location of the GPS laid out sampling points are centred within a 20 m circle of the projected sampling point (large circles in Fig. 2). Deviations from this pattern occur not due to errors in GPS-obtained coordinates but due to geological and geomorphological terrain characteristics, e.g. outcrops, sub outcrops and flood plains of streams.

5. FINAL NOTES

We have shown that the use of the GPSr in the lay out of a grid used for a regional exploration programme was undertaken and completed in a fraction of the time that it would have taken using conventional compass methods. Time and, most importantly, money were saved. As the GNSS technology becomes ever more accurate, cheaper and GPSr's are easier to use, it is our opinion that with respect to the original question asked in the title of this work, the answer is a resounding YES!

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7. REFERENCES

DE OLIVEIRA, D. P. S., 2003. Development of exploration guides for precious metals in ophiolite complexes: Final report on the work carried out in the Morais ophiolite complex (Trás-os-Montes), NE Portugal. Instituto Geológico e Mineiro internal report, 84p.

http://www.garmin.com/aboutGPS/

http://www.thalesnavigation.com/en/products/aboutgps/

http://www.thalesnavigation.com/en/products/aboutgps/augmentation.asp

http://www.thalesnavigation.com/en/products/aboutgps/dgps.asp

GALILEU: http://europa.eu.int/comm/dgs/energy_transport/galileo/index_en.htm

PEREIRA, E., RIBEIRO., A. e SILVA, N., 1998. Carta Geológica de Portugal, Folha 7-D (Macedo de Cavaleiros), Instituto Geológico e Mineiro.

PEREIRA, E., RIBEIRO, A. e CASTRO, P., 2000. Notícia Explicativa da Folha 7-D Macedo de Cavaleiros, Instituto Geológico e Mineiro, 63p.