From paper maps to a new geoscience digital store: cartographic developments in the Precambrian geology of central and northern Madagascar. *P Turner[1], M Piovarci [2], D Tragheim[1], L Bateson[1], B Chacksfield[1].*
1 British Geological Survey, 2 DataImage, Bratislava.

A recently completed geoscience project in central and northern Madagascar has created a modern Geographical Information System (GIS) database from which multithematic products and maps can be generated. The base materials for this output were the classical geological compilation maps of Bésairie et al and Hottin in the 1970's. Both geological and topographic hard copy data were transformed to georeferenced base line data and were complimented by modern vector and raster data such as Shuttle Radar Topography Mission (SRTM), Landsat Enhanced Thematic Mapper (ETM) and Aster spatial data. New airborne geophysical data made a significant contribution to the interpretation of the geology and these new thematic maps guided the field geologists in their selection of mapping and sampling sites. The resulting geological, geomorphological and minerals data were constructed into ESRI ArcGIS databases which can be searched for thematic layers and be represented cartographically at any scale from 1:100 000 to 1:1 000 000.

Use of Landsat ETM and Aster

Original processing of Landsat ETM data produced a false colour country wide mosaic with a 742 band combination. Landsat ETM data in Madagascar was found to suffer from two issues; namely cloud cover and a very strong vegetation signal. Due to the difficult nature of fieldwork the remotely sensed data was heavily relied upon for geological interpretation. Therefore it was necessary to address both of these issues. The original Landsat data was supplemented with imagery from different dates. Careful selection and mosaicing allowed the level of cloud to be much reduced. To reduce the overriding effect of the vegetation the imagery was segmented and processed on a sheet by sheet basis. The local image statistics were accounted for and the most appropriate band combination and processing technique could be selected depending on the vegetation density, topography and landcover type within the map sheet. Three different band combinations were selected: 742, 452 and 752, all images were then carefully contrast stretched, for some sheets it was found that a decorrelation stretch was beneficial. Aster satellite data suffered from heavy cloud cover in some areas but was found to be useful due to its higher spatial resolution. The 15 meter visible and near infrared imagery was processed on a sheet by sheet basis and carefully contrast stretched to allow interpretation. Tests showed that the shortwave infrared data did not reveal any additional geological information over the Landsat; a result of the dense vegetation and deep weathering profile.

Use of SRTM and 3D interpretation

Using new SocetSet digital photogrammetry software, 3D synthetic stereoscopic images were made by combining the SRTM elevations with several raster datasets such as the false-colour Landsat ETM composites, and airborne geophysics (K-Th-U radiometrics, and shaded-relief magnetics and pseudo-gravity). The radiometric and magnetic data was particularly impressive in the rain forested areas; by defining soils directly related to the underlying rock types, and revealing enormous structural refold patterns. The magnetics showed subsurface as well as surface structures important for mineralisation. Using this technique it is possible to use multiple stereo windows, and overlay other 3D vector information such as existing geological boundaries. This

allowed complementary relationships between the various datasets to be examined, and new boundaries to be digitised using a 3D terrain tracking cursor.

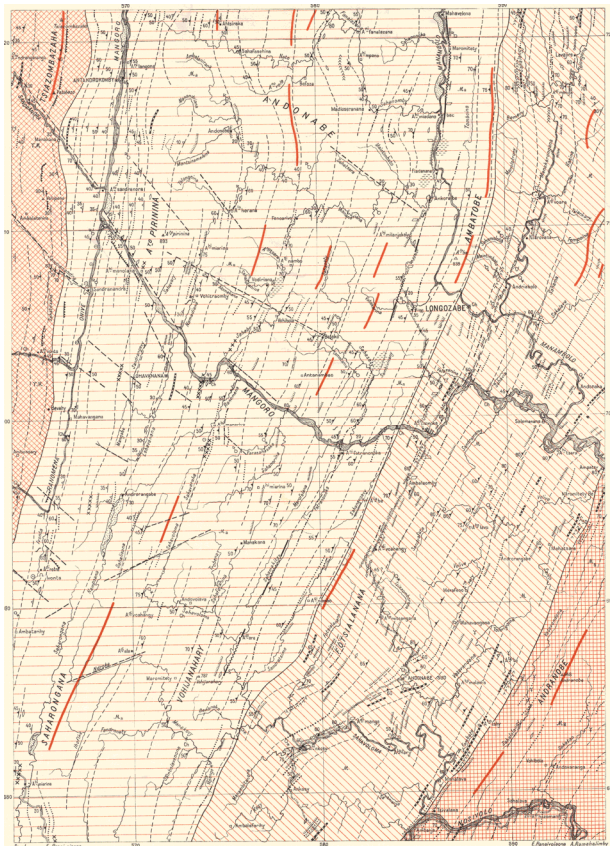
Geophysics

New 'high-resolution' airborne magnetic and radiometric surveys have made a major contribution to the re-interpretation of the surface geology and subsurface structure of Madagascar and guided the field geologists in their selection of mapping and sampling sites. In northern Madagascar magnetic maps have identified many concealed igneous dykes, deep seated intrusions and arcuate fold structures eg. the Massif du Tsaratanana; and have shown the internal structure and margins of the Cretaceous lavas in detail. In the central region of Madagascar combined magnetic and radiometric data reveal the full extent of the fold structures within the granitic migmatitic belt in detail and have identified major geological terranes. The internal structure and fractured nature of the Ambatovy Complex displayed in the geophysics imagery and the associated high Nickel geochemical values make this an exciting mineral prospectivity target.

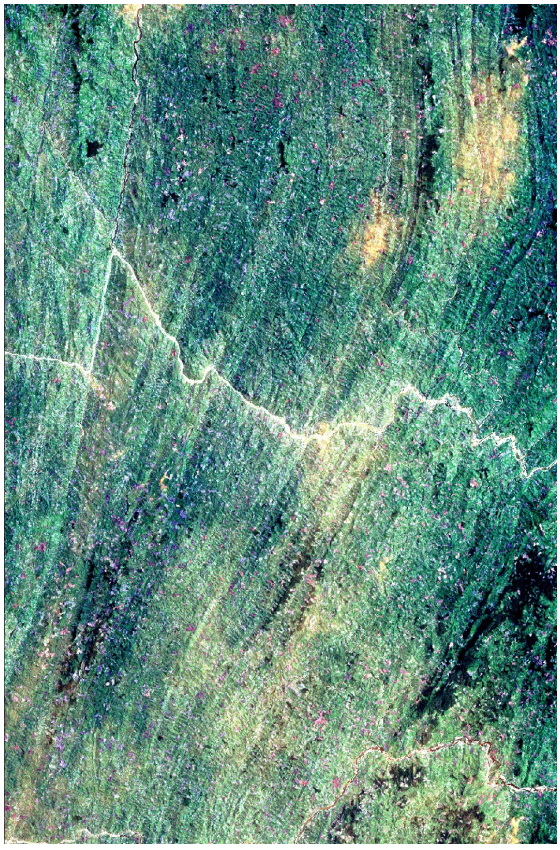
Use of GIS

The use of GIS in the project was two fold; to aid the geologists when compiling new maps and to use new data sets to create map products and a database of information layers. Old data, such as scans of the original 1:100 000 geology maps and 1:100 000 topography maps, were loaded into ArcGIS project files along with new datasets such as Landsat ETM, SRTM, airborne magnetic and radiometric survey imagery to allow geologists to reinterpret the geology on screen and plan field traverses accordingly. The GIS was loaded onto field laptops and used to make multilayered paper maps for taking to the field to aid field interpretations. Once field work was completed mineral locations, field observations, geochronology and pressure/temperature measurement point data sets were used in the GIS to help the geologists compile maps. Geological map data were digitised at 1:100 000 into a geodatabase of point, line and polygon layers for each of the 98 maps in the project. The maps were edge matched and a layout made conforming to a template provided by the client. Cross sections and individual legends were added to the layouts to complete the maps. A merged set of data for all the maps was completed and used to help create thematic diagrams for the project report. The merged data sets were also used in the creation of a series of 1:500 000 overview thematic maps of the geology, structure, geomorphology, hydrogeology and metallogeny.

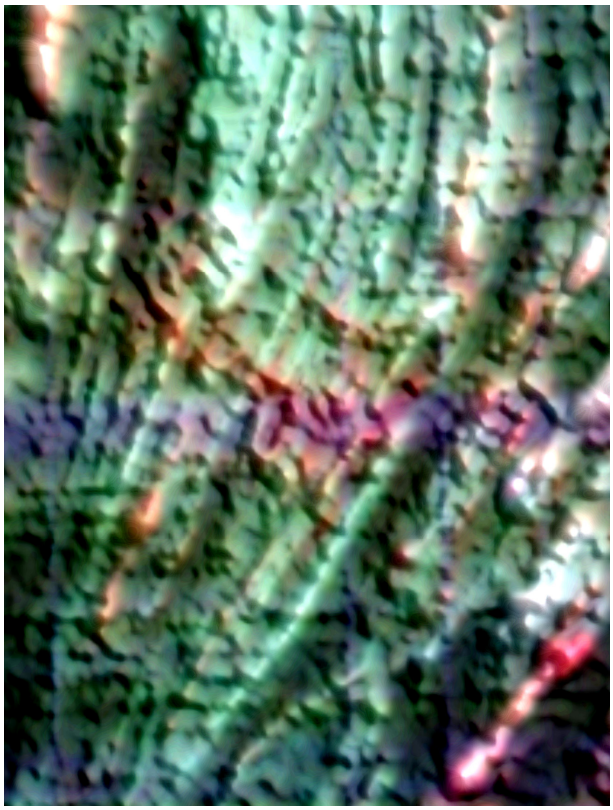
The result of the project is firstly a series of new paper maps which update the Bésairie maps. More importantly by using a GIS there is now a structured set of data layers which contain important attribute data not available to paper map users which can be analysed and used to create thematic maps at a variety of scales.



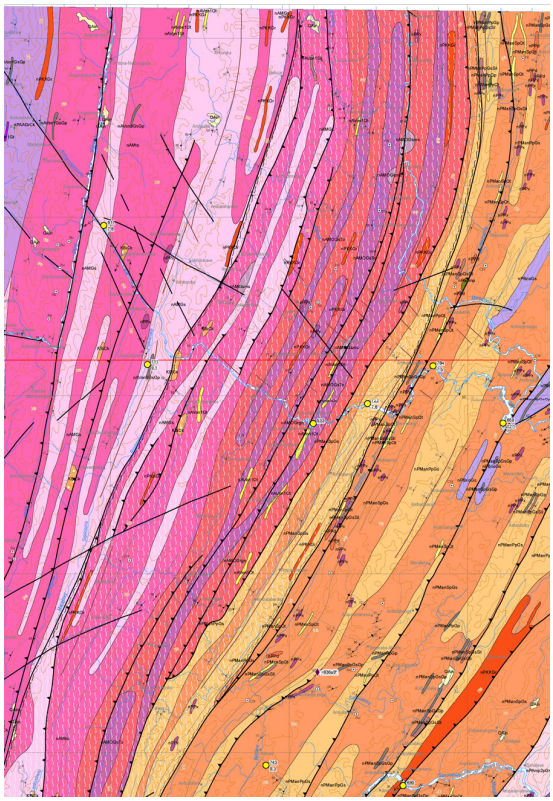
Original 1959 geological map (Bésairie et al.)



Landsat ETM 742 (RGB)



Ternary radiometric image overlain on SRTM data



Final geological map

Examples showing the original and updated geological maps for sheet R49 and three of the imagery types used for the reinterpretation, the Landsat ETM image and an enhanced ternary radiometric image overlain on SRTM data