Geovisionary™ software for 3D visualisation and petroleum exploration in southern Tajikistan

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Summary

In spring 2008, Tethys Petroleum started a programme to explore the 35,000 square kilometre Bokhtar area of Tajikistan, an area the size of Switzerland and equally mountainous. Existing conventional oil company data in the area consisted mainly of elderly Soviet era geological maps, well logs and very sparse dubious seismic, all in paper format. The size and remote nature of the area made it an ideal candidate for remote sensing technology and 3D visualisation, which were used to plan the field geology and seismic acquisition and to complete the first phase of the exploration programme on time. BGS used GeoVisionary™ software in an immersive suite to produce the three-dimensional visualisation. A rear projected screen with stereo viewing glasses allied to the 'Geometry' tools were used to digitise new geological linework as shapefiles onto 3D perspective views of the terrain. This functionality was also used to plan the field traverses in order to maximise the time in the field.

1 Introduction

Tethys Petroleum created history when they signed the first ever Production Sharing Contract (PSC) awarded in Tajikistan. It covers a large region comprising approximately 35,000km^2 in the south of the country (Figure 1). Exploration drilling is required by 2010, which at the time of signing left eighteen months for geological studies, seismic acquisition and processing. A remote understanding of the geological model was a prerequisite to enable a quick start to the first phase of exploration and to help plan 1000kms of seismic acquisition. Existing information included historical 20-40yr old datasets such as well logs, analogue seismic lines, Soviet geological maps and prospect mapping / interpretations based on surface structures.

Figure 1. The exploration area comprises approx 40,000km 2 in southern Tajikistan

The BGS was tasked by Tethys Petroleum with evaluating the existing information, and building a digital 3D model including new satellite data acquisitions. The model was compiled in Geovisionary™ and reviewed by the team in a 3D immersive suite prior to undertaking targeted fieldwork with Tethys geologists. The office-based remote sensing interpretation and 3D visualisation provided a regional understanding of the stratigraphy and structure, enabling the field team to subsequently verify the remote sensing interpretations, and to build confidence in the accuracy of existing (and revised) geological maps and sections. The fieldwork provided a very general overview of the structure, tectono-geomorphology and stratigraphy of the basin. The data were taken to the field on a Tablet PC running the BGS·SIGMAmobile system, which enabled continuation of the digital workflow. All of the digital data were to hand at the outcrop and efficient transfer of newly-collected field data back into the 3D model was ensured.

2 Geological Context

Oil was discovered in the PSC in 1909 but no real investment was made in the last 20 years although there is a low level of current production from the Beshtentyak oil and gas field near Kulob (Figure 2). The figure also illustrates that the PSC area is the Tajik Basin which is an extension of the gas prone Amu Darya Basin of Uzbekistan and Turkmenistan. Oil is found in two areas, the northern Fergana basin and the southern Afghan Tajik basin, the subject of the abstract. To date most production has come from the Fergana but the Afghan Tajik block is the extension of the prolific gas prone Amu Darya basin and shares the same pre Neogene stratigraphy. In the Bokhtar area there are several discovered oil and gas fields some of which are in limited operation. The Palaeozoic basement is overlain by Permian and Triassic. Above these lies the principle hydrocarbon bearing section from the Jurassic to the Palaeogene; continental Jurassic which is the gas source, middle and late Jurassic carbonates and evaporates deposited in the Tethys ocean and overlain by salt and anhydrite, early continental Cretaceous and later Cretaceous and Palaeocene marine carbonates and clastics including the main reservoir in the Bokhtar area, the Bukhara limestone. The overlying Eocene basinal marine mudstone is the primary oil prone source rock.

Figure 2. Location of the Kulob area, which has low current oil and gas production

Large scale north-south folds and thrusts, and east west strike slip plus movement of the Jurassic salt have created numerous traps and structures (Figure 3). The Tajik Basin is a lozenge-shaped intermontane basin separated from the Pamirs by the Darvaz-Karakul left lateral strike slip fault/thrust, whilst it is separated from the Gissar Range by the Gissar fault belt, a major right lateral strike slip zone. At the western edge the basin has been overturned by the SW Gissar Range. The southern extent of the basin is delimited by the Alburz-Marmul fault, marked by discontinuous fault scarps with right-lateral and oblique thrust displacement that bound a large, active NNE-trending pressure ridge to the south. Within the basin are a series of anticlinal ridges striking nearly N-S, which swing into parallelism with the Gissar belt to the north. It was very important to gain a better understanding of the structural elements and any neotectonics is order to assess the viability of the basin for exploration.

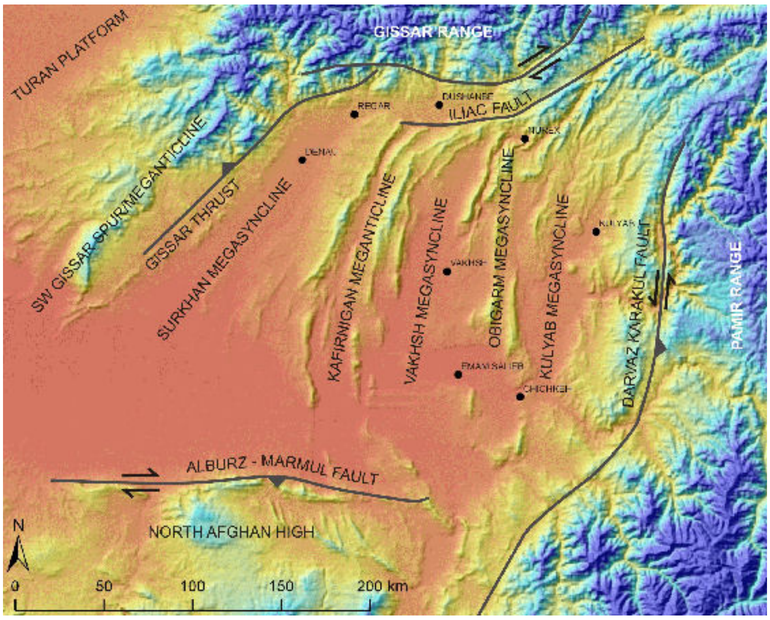

Figure 3. Present day structural elements of the Tajik Basin

3 Remote Sensing Imagery and Legacy Datasets

A model was built using a variety of satellite imagery and legacy datasets. The satellite imagery comprised of four Landsat and twenty-one ASTER scenes (Figure 4), whilst the terrain surface was derived from SRTM and DTMs made from ASTER. Legacy data included geology maps, seismic profiles and well logs, all of which had to be scanned and georectified.

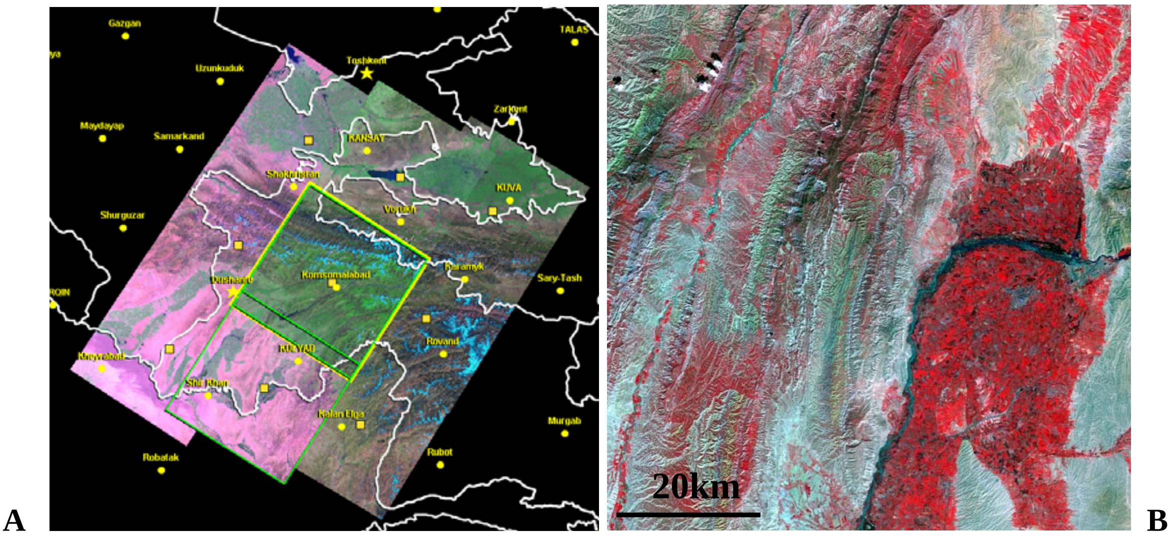

Figure 4. A) Landsat coverage of SW Tajikistan; B) subset of an ASTER image

SRTM data were downloaded for the area, holes filled and the data mosaiced; this mosaic formed the basis for the 3D visualisation. All three images from the 21 ASTER scenes were othorectified against the SRTM, the SWIR and VNIR data were then combined and resampled to 15m resolution. TIR data were not used in this study due to their lower resolution and the detail required by the visualisation. Various false-colour composites were trialled to find the most suitable band combination for geological discrimination and visual interpretation by geologists. Bands 321 and 631 in RGB were found to offer the most information and ease of interpretation. Contrast stretches were carried out on geologically important areas to ensure that the maximum information was present. All images were then colour balanced and two mosaics were produced. ASTER DTMs were produced for sample areas, however the time overhead for editing 21 DTMs together meant that the SRTM was used for the regional interpretation.

Tethys have a wealth of old Soviet era data, this is all in analogue format. A concerted effort was therefore required to digitise the data and then organise it in a GIS. Paper maps were scanned and georeferenced and cross sections were digitised as three-dimensional shapefiles, which could be directly opened in GeoVisonary™ along with the Segy seismic files. Geological models of lithological units, fault plains and exploration wells were converted from petrel to GeoVisonary™ format.

4 3D Visualisation and interpretation

Novel 3D visualisation was a prerequisite in order to gain an understanding of the complex geology and to focus the fieldwork and geophysics campaigns. Furthermore, remote sensing and visualisation were exceptionally useful because of the proximity of part of the field area to the sensitive Afghanistan border region where fieldwork is restricted. The project needed a software system capable of integrating and visualising the full array of satellite imagery with scans of seismic data (in the form of cross-sections) and well logs in 3D. In order to build a complete understanding of the 3D geology, it was also necessary to have the functionality to add linework while viewing the model in stereoscopic perspective. This could only be achieved using the GeoVisionary™ system, which was co-developed by Virtalis Ltd and BGS.

In order to optimise the data for fast navigation the terrain models and satellite imagery were converted to the GeoVisonary™ proprietary Virtual Streaming Image (VSI) format which enables rapid access and graphic display of extremely large datasets. A rear projected screen with stereo viewing glasses allied to the ‘Geometry’ tools were used in the BGS immersive 3D stereo facility to digitise new geological linework as shapefiles onto 3D perspective views of the terrain. This enabled the field team to conduct ‘virtual field reconnaissance’ and also to plan focussed field traverses in order to maximise their time in the field.

Figure 4 illustrates a selection of the types of views that were used to incorporate legacy data into the visualisation, and also to construct a revised understanding of the 3D geology prior to and after fieldwork. Figure 5 (A) consists of a perspective view of Landsat data with superimposed interpretative linework. B consists of ASTER imagery draped onto the SRTM whilst C incorporates terrain measuring tool that enables geological structures to be measured remotely prior to confirmation in the field. D, E and F show one of the Soviet era cross sections in comparison to the imagery, the terrain and the revised geology.

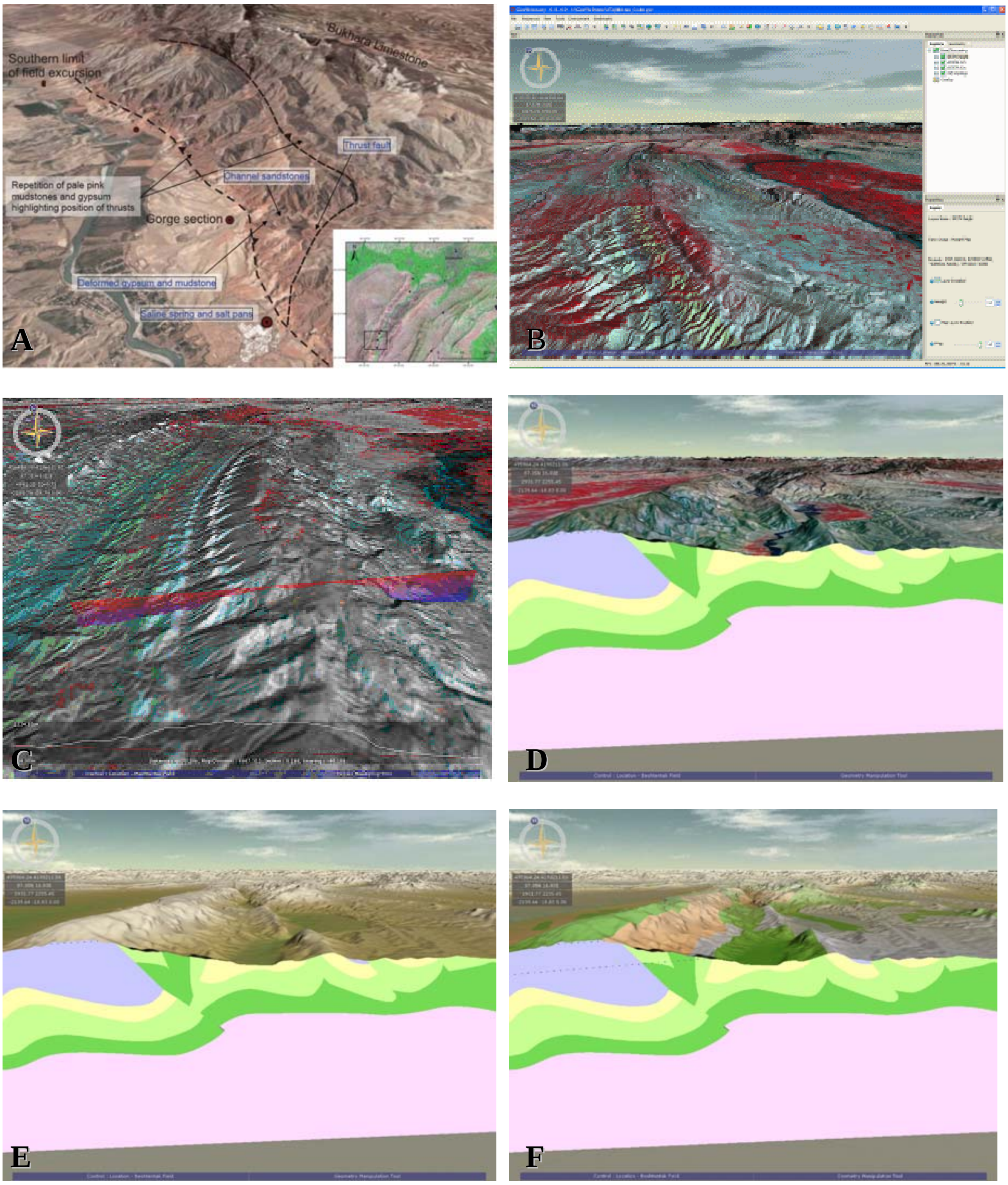

Figure 5. Examples of GeoVisionary visualisations. A)incorporating linework and field traverse plans on Landsat, B) thrust planes visible on ASTER data, C) profile tools used to measure thrust planes and dip slopes, D, E, F) Soviet cross-section compared against ASTER imagery, shaded DTM and revised geology.

5 Conclusions

The unique capability of GeoVisionary™ to integrate and stream very large datasets from multiple sources for visual comparison, and subsequently to add new linework and measure structural features in 3D stereo perspective enabled existing data to be assessed and revised efficiently. The use of the BGS immersive 3D visualisation suite added to the experience and facilitated a team of geologists to work effectively together on the same model. Prior to fieldwork the legacy model was revised, 3D shapefile vector interpretations were added, and field traverses were plotted. The data were taken to the field using a BGS digital field mapping system (BGS·SIGMAmobile) and newly collected field data were subsequently reinterpreted in 3D following fieldwork. This efficient digital process of virtual field reconnaissance, combined with traditional focussed fieldwork allowed Tethys to conduct their exploration on schedule and plan their seismic campaign with confidence.

6 Acknowledgements

This paper is published with the permission of the Executive Director of the British Geological Survey (NERC).