APPLICATION OF NEW REMOTE SENSING TECHNIQUES TO GEOTHERMAL EXPLORATION AND ENVIRONMENTAL MONITORING

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Abstract

Clear scattering radar images can obtain even if the area is covered by clouds and dense vegetation. Geological features, such as lineaments and circular structure, are successfully identified at southwest of Negros Island, the Philippines, by using such radar images. We are now studying interferometry analysis of SAR {Synthetic Apature Radar) images that provide us few centimeters present day crustal movement and thus applicable for monitoring of land subsidence of geothennal area. Good correlation between annospheric and ground temperatures are recognized by the ground truth thermal infrared survey of Thauhara area, New Zealand. It becomes basic data for planning heli-bone remote sensing infrared survey. Remote sensing using conventional spectral data also useful for geological analysis. Combined with soil gas survey, oil and gas showing zone is selected in China. Our studies are not limited for geothennal areas but the remote sensing techniques described above can easily be applied for geothermal exploration and environmental problems.

1.0 Introduction

Remote sensing technology is progressing continuously but it is not so easy to precise geological interpretation by the data from space. However, special radar image data (SAR, Synthetic Aperture Radar) give us new ideas on geological structure by scattering images and also provide us few centimeters present day crustal movement by interferometry analysis. Conventional LANDSAT and newly developed satellite images are also used for more detailed exploration in many areas. Thermal infrared images can also be used fur detecting surface temperature anomalies. Such remote sensing techniques are applied not only for geothermal exploration but for mineral exploration, oil and gas exploration, and many other fields in Earth observation.

We are introducing the results of such techniques applied for metal mining at Negros Island, Philippines, future application of interferometry analysis of SAR images, and accurate surface temperature determination by thermal infrared images at the Mt Tauhara area, Taupo Volcanic Zone, New Zealand. Additionally, we will discuss the chemical techniques applied to identify the oil and gas emanation zone from satellite images.

2.0 Scattering SAR Image Analyses of Negros Island

A SAR image data of southwest Negros Island, Philippines centered on 9.52.59N latitude and 122.24.00E longitude was processed by Advanced Precision Processor (APP) software in the ERDAS-IMAGINE Version 8.3 software. The purpose of the study is to identify lineaments, circular structure and other geologic features which may control to the Bulawan gold-silver telluride deposit in Sipalay town. The deposit was started to be mined by Philex-PNB in 1995. The mining operations is directed to a low-grade, bulk tonnage mineralization which occurs in narrow outcrops of dacitic subvolcanic intrusives cutting older andesitic lavas. NE-trending faults appear to control the distribution of the intrusive rocks (Maglambayan et al., 1998).

We can get clear radar images even if the area is covered by clouds, less clear images if the area is covered by in vegetation, than conventional LANDSAT image. It is the biggest advantage of using radar images. Using the fully enhanced radar images, we analyzed lineament and circular structures' (Fig. 1). Observable differences in tone and texture of the back-scattered images can reveal heretofore unidentified geologic structures. *preliminary* results after speckle or noise suppression show that bright areas bounded by darker tones appear as short, gash-like lines south and southeast of the deposit. These lines are inferred to be on the scale of 0.5 to 1 km on the ground. The radar image also showed relatively longer N-NE lineaments (2.5 km) which are cutting a few of the shorter lineaments. The contrast between light and dark pixels which form linear patterns will be used to locate similar lineaments. Few circular structures are identified but not so clear. Such structural features show some coincidence to geological data of Burton (1983). At the moment, lithologic discrimination may be difficult although sharp contrasts in the texture

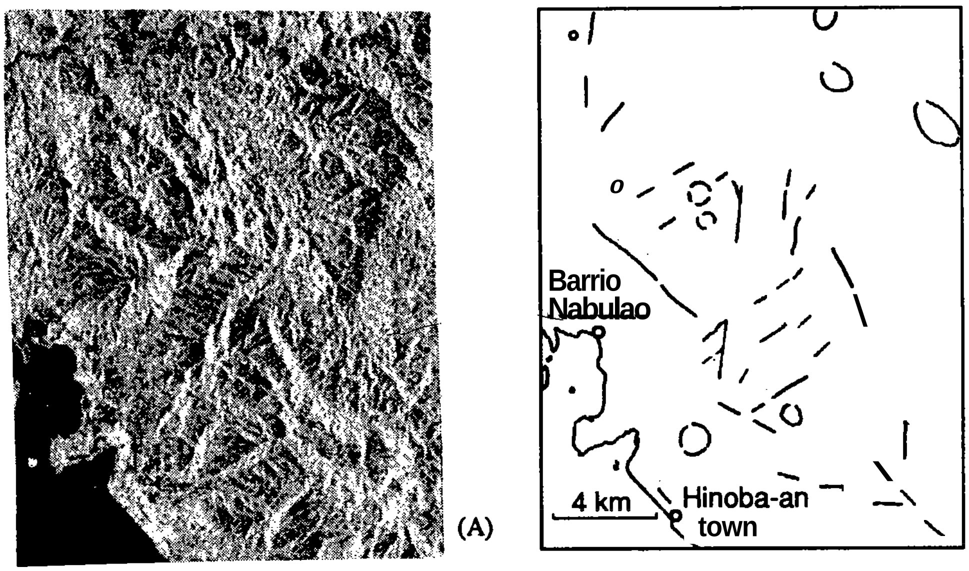


Fig. 1 Radar scattering image (A) and identified geologic structures (B) of southwest of Negros Island, Philippines.

of the slightly enhanced image was observed east of the deposit. This appears to be coincident with the known rock contact between the softer andesite units and a dioritic-granodioritic batholith which is another significant geologic feature in the area. Improvement of the resolution of the image will be done using the available functions of the software (filtering, classification, etc.). The use of aerial stereopairs will also be tried to confirm the present findings. These activities should enable us to locate other geologic structures which have not yet been identified either by remote sensing techniques or by "ground-truth" mapping.

3.0 Future of Interferometric SAR (InSAR) Image Use

The phase difference between two SAR images produces the data to generate digital elevation models (DEM), deformation maps, and temporal change maps. Interferometric SAR (InSAR) images show us mm- to cm- level deformation. The deformation map of the great Hanshin-Awaji earthquake is one of the most famous InSAR images (Murakami et al., 1995). We have just started the InSAR image process to detect land subsidences and landslides in geothermal area at Akita prefecture, Japan using the Atlantis Advanced Precision Processor (APP) and EarthView InSAR software produced by Atlantis Scientific Inc. The data is now being processed. Here we present how to get the raw data. The results of the InSAR study will be presented in the near future.

There are many satellites such as ERS-1/2, JERS-1, Almaz, and RADARSAT that provide InSAR data pair. For InSAR study, two phase preserved SAR images of the same region obtained at slightly different viewing angles are required. Generally ERS data is the easiest data to work with for interferometry because ERS-1 and ERS-2 orbits are well maintained. We, however, use JERS-1 data. The reason is that JERS-1 data is very good for interferometry since it is an L band SAR. Longer wavelengths generally give higher coherence levels as compared with shorter wavelengths. However, the main reason is that one scene JERS-1 raw data on CD-ROM costs only 4200 yen (= ca. 32US$). JERS-1 data is received by the National Space Development Agency of Japan (NASDA) and provided by the Remote Sensing Technology Center

(RESTEC). At the web site of RESTEC (http://www.restec.or.jp) there are plenty of information on how *to* select and order the satellite images. The database of JERS-1 **data** at NASDA is available by connecting to eustty.eoc.nasda.go.jp with rlogin or telnet. We can search for appropriate data by sending many parameters such **as** latitude / longitude, weather condition, date, and so on. The most important data for interferometory is baseline. However, the database for this parameter is not open to the public. If we send the **low** and pass data of satellite to the order desk of RESTEC, they assist us in selecting the ideal InSAR pair by accessing the closed NASDA **special database.**

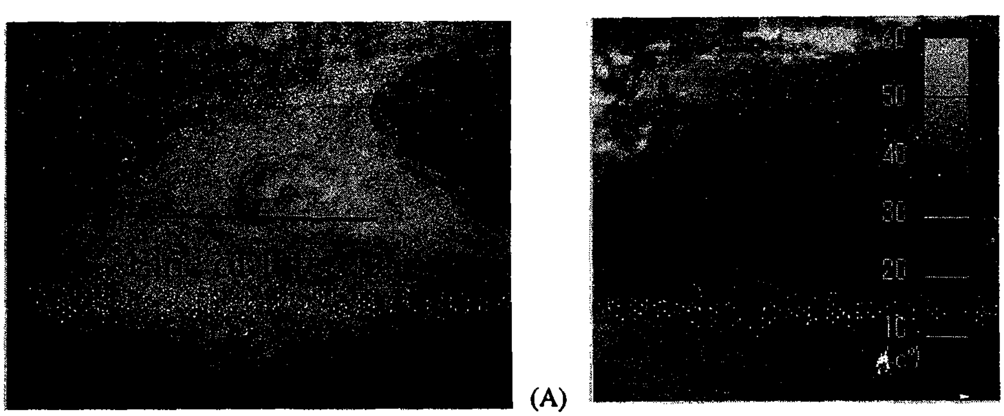
4.0 Thermal Infrared Images Processing at Tauhara Geothermal Area

Among many remote sensing technology, thermal infrared (TIR) camera is the most powerful apparatus for geothermal study, because we can measure directly the ground surface temperature by using infrared radiation.

Delineation and monitoring of surface thermal activity at geothermal development sites, **tourist,** and urban areas are important for safety, planning, scientific and field management reasons. Since the standard ground-based temperature measurement methods employed for such works are incomplete, expensive, and often impractical, Mongilo and Bromley (1992) have developed a helicopter-borne video thermal infrared scanner technique to replace ground-based methods and applied it to geothermal observation at a geothermal area in New **Zealand.**

In Japan, movement due to geothermal activity is also very serious. While hot springs are very important business resources for **tourism** in Japan, there are landslide disasters resulting from geothermal activities. Thus the necessity for monitoring of geothermal activity has escalated. Compared with other countries, the cost of heliborne survey in Japan is very high, very dangerous because there are many steep mountains at geothermal areas and heliborn survey must be performed at night to prevent the remaining heat of sun. Therefore, a **fixed** point observation from another mountain is more realistic in Japan.

We performed a fixed point observation of a large crater beside a school near Taupo Lake in New Zealand with an **NEC** TH3102MR portable infrared camera to check the effect of infrared monitoring. The TIR camera integrates infrared radiation from 8 to 13 micrometers in wavelengths, calculates surface temperature. and produces a temperature distribution map **as** a color image. The range of detectable temperature is from **-50** to 2000°C and the maximum resolution of temperature is 0.1°C. Figure 2 (A) shows a photograph of the survey area. The width is about 10 m. This crater suddenly formed two years ago that residents became anxious about its expansion. Figure 2 (B) is the thermal infrared image of the **area.** The temperature bar indicated **at** right side is not calibrated with radiation rate. Calibration was done by comparing with the direct measurement of ground surface temperature using thermocouple, and the difference b e e n TIR temperature and thermocouple temperature was less than 2°C. We took TIR images every 10 minutes from 18:00pm *to* 22:30pm on November 22,1997. Figure 3 shows temperature change of the ground line shown in Fig. 2 **(A).** The length of the line is 6 m. All images were combined to dimensional block (image x time dimension) and we sliced the block with line of interest - time plane by



(A) (B)

Fig. 2 Photograph of school-side crater **(A)** infrared image of central part (B) of Tauhara geothermal area, New Zealand.

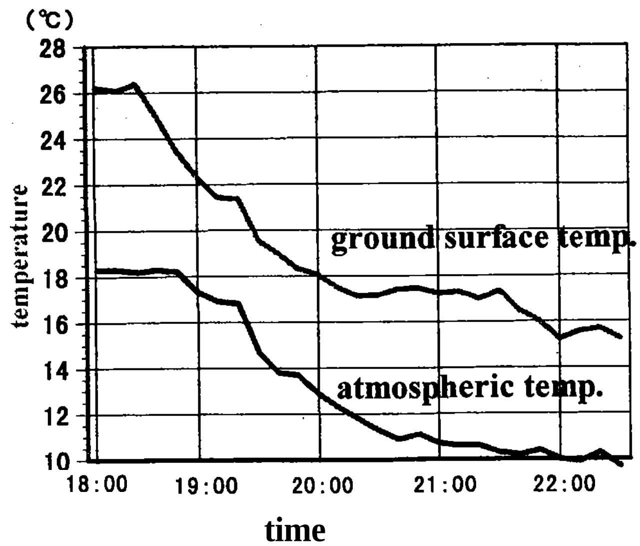


Fig. 3 Average temperature change at the line of interest in Fig. 2 (A).

using image analysis program Image PC constructed by Scion Corporation. Then the average temperature change of the line is calculated. That day, sunset was ca. 8:20pm. Just before sunset, the remaining heat became smaller and smaller and ca. 30 minutes before sunset, it became nearly constant The data shows that **TIR** images show temperature distribution and its change very clearly. The data indicates that it is not necessary to wait until midnight for air-born survey. Of course, it depends on weather (temperature, humidity, wind, etc.) and amount of heat flow in the area. Heli-borne study of this area (Mongillo and Bromley, 1992) uses the remaining heat of the road as ground control point. Dr. Mongillo, **IGNS,** New Zealand, told us his pilot hates night-flight, therefore it is not a simple problem how to decide the time of airborne survey even if the ground temperature is stable at night. The fixed point monitoring gives us useful data to decide the ideal airborne survey time and in case that the time has not been ideal, the data suggests to us how to estimate the real amount of heat flow.

5.0 Chemical Exploration Interpreting the Remote Sensing Data in China

One of **the** conveniences of using remote sensing data is that we can find out wide ranging geological information that are difficult to discover from our geological investigations on the surface. Especially, in cases where we want to obtain geological information below the surface of plain and basin showing topographically flat surface, remote sensing data is one of the best methods for extracting surface influences or indications.

Figure 4 is a result of case study using remote sensing data such **as** LANDSAT/TM and JERS-1 in the Tarim basin, northwestern part of China. In this study, indirect geological information relating to geological features under the surface can be extracted by processing and interpreting remote sensing data on the surface. **This area** is known for its high potential for hydrocarbon deposits. Furthermore, prospecting and development for oil and gas are still continuing. The area is covered by Quaternary sediments consisting of fan deposits and stream deposits, and topographically conditions on the surface show flat plane. Oil and gas reservoirs in the area occur in Paleozoic to Cenozoic strata of the approximately 4,000m to 6,000m below the surface.

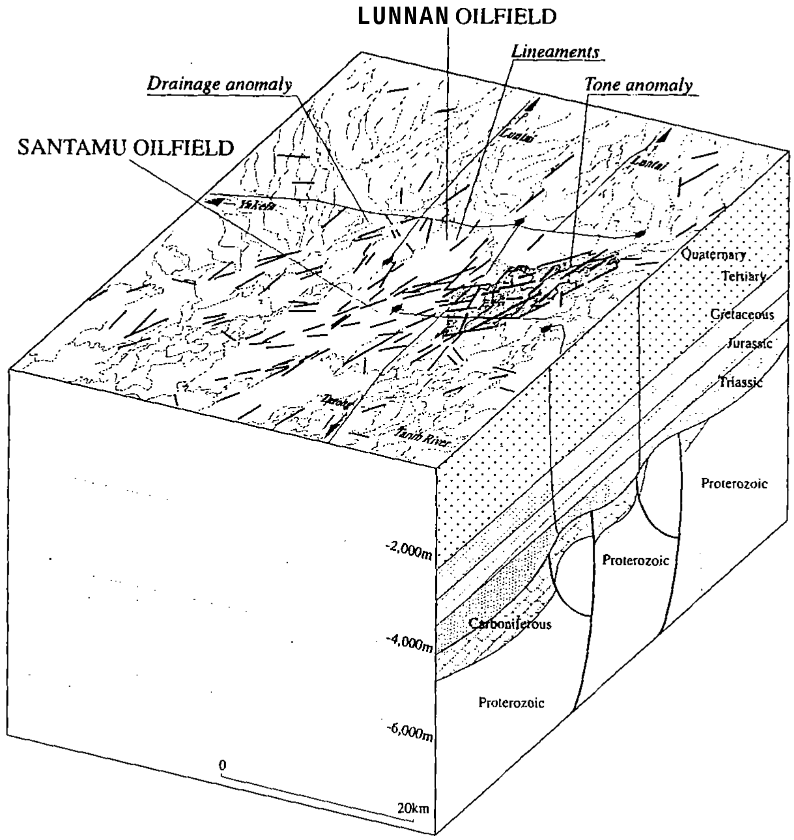


Fig. **5** Block diagram in Lunnan and santamu Oilfield in Chian (after Negishi et al., 1997). High concentration of methane is observed at lineaments swamp and tone anomaly **area.**

The purpose ***of*** processing and interpretations using remote sensing data in this study is to extract tone anomalies by using spectral index on visible band and/or near-infrared band, and lineaments are shown as a track of fissures on the surface. As the result of investigation, lineaments and tone anomalies, which are regulated by lineaments, extracted from remote sensing data were converged in certain area. Actually, hidden geological structures, showing oil and gas traps under the surface, in the **area** were defined after carrying out **the** above interpretations. For these reasons, it was assumed that the surface influences and/or indications are closely related ***to*** oil and **gas** deposits and hidden structures under the surface.

As a next step in this study, assaying of light hydrocarbons in in-situ soil was carried out to test the above interpretations. As the result of this assay, it was verified that light hydrocabons show oil and gas showing, and methane in the light hydrocarbons shows high value on the extracted lineaments. These results imply that such lineaments and tone anomalies contribute to surface influences or indications that are closely related to subsurface geological features such **as** hydrocarbon resources and hidden geological structures.

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