HOW THE BURABURI GRANITE (Dolpo-Western Nepal) WAS DISCOVERED THROUGH REMOTE SENSING ANALYSIS AND GROUND TRUTH

Ph.D. candidate: LUCA BERTOLDI
Tutor: Prof. DARIO VISONA, Dott. MATTEO MASSIRONI
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INTRODUCTION

More than forty years ago Fuchs and Frank (1970) speculated the presence of a granitic body (Buraburi Granite – BG) with very uncertain boundaries between Dolpo and Mugu Karnali regions (Nepal), about ten kilometers western than Kanjiroba massif. In particular the authors interpreted it as the southern portion of the bigger Mugu granite which is located further to the north. Until that time only Arita et al. (1984) have reported the presence of a large granite body emplaced into the both Higher Himalayan Crystallines (HHC-Samla Pass schist) and Tibetan Sedimentary Sequence (TSS-Dhaulagiri limestone) in the northeastern area of Dolpo region. Despite they have briefly discussed various granite rock facies (tourmaline granite with or without garnet, biotite granite and muscovite granite), no one sample was analysed. Consequently in the most recent official maps and papers, this granite disappeared and the Mugu granite was hence confined to the north of the Mugu Karnaly river (Harrison et al., 1999).

Data from the Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) were used to locate and study the BG which was afterward confirmed by a ground truth mission. We have performed a petrographic study on thin sections of the samples collected using both optical microscope and microprobe. Furthermore some rock samples was analyzed with a spectrophotometer in order to compare the satellite with laboratory spectral signatures.

In the following we will briefly describe the remote sensing method that allowed us to rediscover and correctly mapping the BG. The work-flow started from the image raw data pre-processing and followed with the spectral analysis and comparison between field and laboratory data. All the study were performed using a Geographic Information System (GIS) to visualize, interpret and map the images.

The laboratory and ASTER spectral data show an unlinear mixing between granite and lichens signatures. The mixed signature has been used as a proxy of the BG demonstrating its potential for mapping the intrusion contacts in the area.

1. ASTER DATA AND PREPROCESSING TECNIQUE

The ASTER data are among all the satellite optical products the far most useful for private user since they are cheap and with a good world coverage. However the accuracy of these products is limited mainly by the moderate spectral resolution of its bands.

ASTER is a push-broom sensor with three radiometers. The first has three VNIR (Visible-Near Infra-Red) bands (15 m/pixel), the second has six SWIR (Short Wave Infra-Red) bands (30 m/pixel), and the third has five TIR (Thermal Infra-Red) bands (90 m/pixel). Moreover ASTER has an off-nadir band, the 3B band, it is identical to the NIR band 3, except with a view of 23.5 degrees relative to the nadir-looking telescope. The combination of these two bands allow the generation of a DEM (Digital Elevation Model) with a 15m grid.

The remote sensing analysis was carried out using IDL-ENVI® and ESRI-ARCGIS® software on ASTER L1B and L1A data.

The Level-1B data product can be generated by applying radiometric coefficients to perform the RADIOMETRIC CALIBRATION and GEOMETRIC RESAMPLING of Level-1A data. In this way the DN (Digital Number) becomes a radiance at sensor (W/m²/sr/µm).

The following preprocessing steps were applied on Level-1B:
1) correction of the SWIR bands crosstalk effect (Hewson et al., 2005)
2) DEM extraction using the stereoscopic images: Band 3N and Band 3B
3) SWIR and TIR bands resampling at 15m/pixel
4) correction of SWIR-VNIR geographic shift
5) orthorectification
6) conversion of VNIR-SWIR bands from *radiance at sensor* to *ground reflectance* and TIR bands into *ground emittances* (ATMOSPHERIC CORRECTION)

7) correction of topographic effects using SRTM data conveniently resampled and interpolated, preferably using a non Lambertian method like Minnaert Correction or more complexes Teillet and C-correction methods that use empirical-statistic approaches. (Riano et al., 2003; Twele et al., 2005; Nikolakopoulos et al., 2006)

### 2. ASTER PROCESSING

Detailed lithological discrimination, especially near or above particular objectives like vegetated and topographically rough areas, requires advanced digital image processing techniques. A good approach consists on masking no bedrock pixels through a classification based filter excluding water, snow, vegetation and clouds. Looking at the distribution of rocky pixel reflectance values in a multidimensional visualizer we were able to cluster them in few end–members, each one with a particular spectral signature. The comparison between end-member spectral signatures and granitoid signatures previously collected in other ASTER images (Himalaya, Corsica, Morocco) allowed us the distinction of granite-like signatures. A SAM (Spectral Angle Mapper) and a MLL (Maximum LikeLihood) classification with such signatures helped us to find the BG and derive its real spectral signature on ASTER data. In order to refine the pluton boundary, on the basis of the study of Yamaguchi et al. (2003), Ninomiya et al. (2005), Rowan et al. (2005), Massironi et al. (2008) and looking to end-member spectral features of ASTER data, we have chosen several mineral-rock indices and characteristic band operation. The 5*7/6 operation and the 5/6 and 7/6 bands ratios underline the spectral shape in the middle of SWIR sensor, a zone affected by the characteristic Al-OH and OH adsorptions peaks in phyllosilicate (Muscovite), while the 5/4 bands ratio highlight the Fe-OH vibrational absorption peaks in Fe-silicates like Biotite and Inosilicates.

The thermal bands have proved to be useful over arid and relatively flat terrain target (Morocco), however in the high relief Himalayan zone studied the emissivity is much strongly affected by the topography than the particular material investigated.

### 3. LABORATORY SPECTRAL SIGNATURES

Twenty-five samples of BG granite and the surroundings rocks, collected during the 2008 field campaign, were analyzed in the VIS/SWIR spectral range at the DEI (Department of Information Engineering-Università di Padova) using the VARIAN-CARY5000 spectrophotometer. In particular the spectral signatures were collected using an Integrating Sphere in wavelength range between 350nm and 2500nm at a 1nm sampling step.

The high-resolution spectral signatures were resampled simulating the ASTER bands filter. This transformation reduces considerably the ability to discern different spectral signatures, obtaining 9 bands from the 2150 laboratory “bands”. Nevertheless the comparison between ASTER and CARY5000 spectral signatures pointed out how the BG ASTER spectra are influenced by the lichens cover. These were also well documented during the 2008 fieldwork.

The lichens diagnostic absorption peaks between 1490-1900nm (ref) in the high-resolution laboratory spectral data is well distinguishable from the Muscovite-Biotite -OH peaks in the same spectral region. Unfortunately this spectral range is hidden by CO$_2$ and H$_2$O atmosphere absorptions in the satellite data precluding a clear discrimination between lichens and granite. Despite that, the comparison between the resampled samples signatures with the ASTER BG signature points out that the VNIR bands are more influenced by the lichens cover (*red-edge*) than the SWIR bands. The latter are more related to phyllosilicates (Muscovite) absorption peak due to Al-OH vibrational-rotational phenomena.
3. Results

The highlights of AlOH absorption peaks shows encouraging results since the Muscovite is one of the principal mineral in the peraluminous Himalayan granitoid. Often in the BG muscovite is present even in giant crystals (5-10 cm diameter), contributing to the high Al$_2$O$_3$ bulk rock content which is an important parameter to classify the granitoid rocks.

Using statistical MLL and signature based SAM classifications, and False Color Band Ratio composite over ASTER image in a GIS environment, we generate a geological map that highlights the BG shape and the surrounding tectonic units.

Some authors (Law et al., 2006) concluded that Oligo-Miocene leucogranites are restricted to the footwall of the South Tibetan Detachment System (STDS), into the high-grade metamorphic rocks of the HHC. Despite that, the contact’s shape seen in the ASTER image between the BG and the TSS, excludes the presence of the STDS), highlighting a much more complex tectonic evolution and kinematic relations between pluton emplacement and STDS activity. The 2008 field investigations sustain these preliminary results, confirming the presence of the BG both in the HHC and TSS.

These findings have substantial implications for the time-extent and even existence of the assumed extrusion and/or channel flow mechanisms which would have driven the exhumation of the HHC also in this area (Carosi et al., 2009).

References


SUMMARY LAST YEAR’S ACTIVITY

Courses:

P. OMENETTO: “Mediterranean tectonics and metallogenes”, Dipartimento di Geoscienze, Università degli Studi di Padova.


CENTRO LINGUISTICO DI ATENEO: “Corso DIY, livello B1+”, Università degli Studi di Padova.

THIRD HYPER-I-NET SCHOOL ON HYPERSPECTRAL IMAGING “Data Processing: from hyperspectral images to information”. Collegio Ghislieri, P.za Ghislieri, Pavia, Italy, September 8-11, 2009.

Posters:


Publications:


Other:

- October-November 2009: geological survey in Dolpo Region (Western Nepal)
- Attending to: VII Forum Geoitalia, Rimini 7-11 settembre 2009
- Pre-processing, processing and interpretation of ASTER satellite multispectral images with MATLAB®, IDL®-ENVI®, ARCGIS® software.
- Samples preparation and analysis of Himalayan granitoid with microprobe EMPA at the Department of Geosciences, University of Padua.
- Separation of heavy minerals and powderization of rock samples at the Department of Earth Sciences and Environmental Geology, Alma Mater Studiorum University of Bologna.
Zircons U/Pb dating in BEIJING SHRIMP CENTER, Institute of Geology-Chinese Academy of Geological Sciences, using a Remote Operation System into Milano Bicocca University.

Rock samples’ spectral analysis in VNIR-SWIR region at Department of Information Engineering, University of Padua.