A REGIONAL GIS OF THE CENTRAL ANDES, SOUTH AMERICA - INTEGRATION OF SATELLITE AND GEOPHYSICAL DATA SETS

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ABSTRACT

The Central Andes of northern Chile, southwestern Bolivia and northwestern Argentina are studied by a research project supported by the Deutsche Forschungsgemeinschaft (SFB 267). The main topics of these geological and geophysical investigations are the orogeny of the Andean mountains and the crustal development at an active continental margin. The "Andean GIS" is designed as a tool for data collection, management, overview, analysis and mapping. The integration of different data supports the interdisciplinary work within the research project and provides a base for the exchange of data and ideas between the different geoscientific disciplines of the project. Remote sensing data represent the basic information level in the "Andean GIS". More than 30 geocoded Landsat TM scenes were processed and integrated into the GIS as well as digital elevation models and orthoimages created from SPOT stereo images. The structure of the GIS contains tools for data overview, visualization, and data input for non-GIS experts. The data management and the applications are developed by the GIS manager in cooperation with project scientists. After the initial development during the last two years, the structure and content of the Andean GIS have to be kept up-to-date continuously in order to fulfill its function as a "common link" between the different groups of scientists.

KURZFASSUNG

Die Zentralen Anden im Norden Chiles, Südwesten Boliviens und Nordwesten Argentiniens sind das Arbeitsgebiet des durch die Deutsche Forschungsgemeinschaft geförderten Sonderforschungsbereiches 267. Den Untersuchungsgegenstand bildet die Andengenese und die Krustenentwicklung am aktiven Kontinentalrand Südamerikas. Das "Anden GIS" bildet ein Werkzeug für Datenhaltung, Datenmanagement, Überblick, Analyse und Ausgabe von Daten und Ergebnissen. Die Zusammenführung thematisch unterschiedlicher Daten dient der interdisziplinären Arbeit der einzelnen geowissenschaftlichen Teildisziplinen innerhalb des gesamten Sonderforschungsbereiches. Fernerkundungsdaten bilden eine flächendeckende Informationsbasis im "Anden GIS". Mehr als 30 geocodierte Landsat-TM-Szenen wurden prozessiert und in das GIS ebenso aufgenommen wie kleinräumige digitale Geländemodelle und Orthobilder, die aus SPOT-Stereo Daten extrahiert wurden. Die GIS-Struktur enthält Menuoberflächen für den Überblick, für Dateneingabe und Digitalisierung zur Anwendung durch Nutzer ohne spezielle GIS-Kenntnisse. Das Datenmanagement, die Analysen und Anwendungen werden in enger Zusammenarbeit zwischen dem GIS-Betreuer und den Fachwissenschaftlern durchgeführt und entwickelt. Nach der Startphase des grundlegenden GIS-Aufbaus in den letzen zwei Jahren ist es nun notwendig, Struktur und Inhalt laufend zu halten, damit die Aufgabe des GIS als Bindeglied zwischen den Teildisziplinen erfüllt werden kann.

INTRODUCTION

The Central Andes are studied by a research project supported by the Deutsche Forschungsgemeinschaft (SFB 267). Scientists from the Free University of Berlin, the Technical University of Berlin and the Geoscientific Research Center of Potsdam (GFZ) are cooperating within this project. The main topics of these geological and geophysical investigations are the orogeny of the Andean Mountains and the crustal development at an active crustal margin.

Geological, statigraphical, petrographical, petrochemical, seismic, magnetotelluric, geomagnetic, and remote sensing methods are used to achive this objectiv.

The project area is situated between 20 - 28° S and 71 - 63° W with emphasis on northern Chile, especially the coastal region around Iquique, Antofagasta, Taltal, as well as Calama and the Salar de Atacama, and northwestern Argentina with the Salar de Antofalla. This area extents from the Pacific coast to the Subandean and the Chaco across the Andes.

The large area and the interdisciplinary work within the project make an absolute necessity to the development and implementation of a tool for integrating data sets and the information gathered by the various project groups.

The "Andean GIS" is designed as a tool for data collection, management, overview, analysis and mapping. The integration of the different data types of the project groups from geological, geophysical to remote sensing data supports the cooperations within the research project and provides a base for the exchange of data and ideas between the different disciplines involved.

"ANDEAN GIS"

The regional aspect of the data implies that a large quantity of heterogenous data has to be integrated and organized for efficient usage (Srinivasan & Richards, 1993). That means building of clear structures within the GIS, development of routines and menus for easy input and management of data, development of menu interfaces for effective data and information retrieval. In order

to reach this objective close cooperation between the GIS specialists and the different users is required.

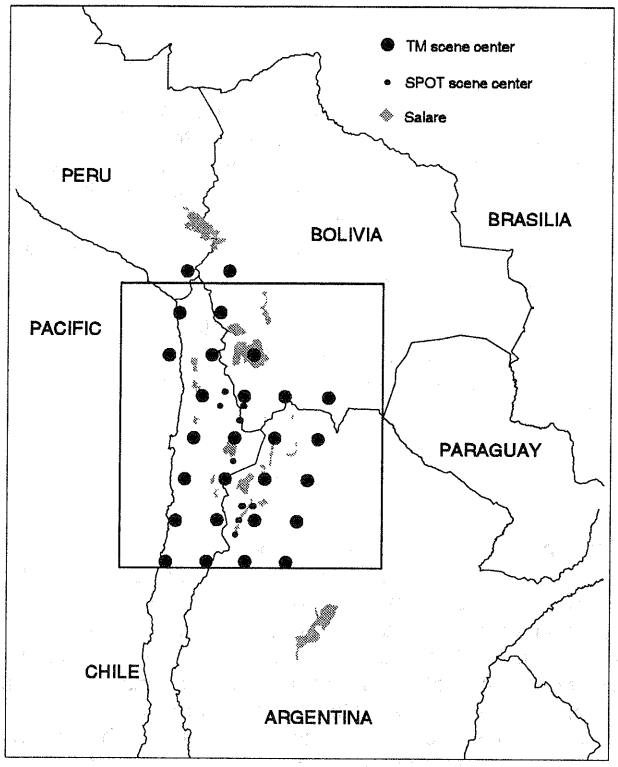

Fig. 1: Work area of the Research Project SFB 267

The software and hardware environment used for the project consists of UNIX workstations linked to a VAX/VMS and a PC pool with the GIS software ARC/INFO and the digital image processing software ERDAS/Imagine. These commonly used software packages guarantee a minimum of data conversion problems between GIS functions and digital image processing work. The output media for maps and image products are an IRIS A0 color proofer and an Optronics color film writer.

Structure of GIS data

The data for the GIS are collected from the different working groups of the Research Project and additional topographic information. For that purpose a data catalog a data catalog which contains data as "raw" files exists.

The data structure is designed according to the main disciplines. Due to the ARC/INFO concept the data are organized in a layer structure.

1. Main directory - ANDES

This directory contains a README, the macros and menus.

The README holds a short description of the structure and contents of the GIS including information about each data coverage, grid or tin and its attribute data.

The macros and menus were developed for the usage of the GIS by different users without special GIS knowledge. The main functions are to bring up an overview menu for searching and overlaying of data in any order or scale. In this menu the user cannot edit, damage or corrupt the data.

For editing, digitizing and converting of data the users get their own workspace and they manipulate their data with the help of the appropriate menus. As background information for editing or digitizing all satellite images within the GIS can be used. This is very helpful for the input of the results of geological field work.

2. Working directories

This level is divided into 6 main themes and contains the following data:

- TOPO: general topographic information, like borders of countries, coast lines, cities, locations of volcanoes, salares etc.;
- GEOLOGY: geological data, like the results of field work, a digital geological map of the Central Andes (scale 1:1.000.000) and different local geological maps;
- GEOPHYSICS: geophysical data, like locations of measurement stations, results of seismic, magnetotelluric or gravimetric measurements by the project groups;
- DEM: elevations models from different sources and with varying resolutions, like grids derived from digitized maps, DEMs derived from remote sensing stereo data and public domain elevation data;
- IMAGES: geocoded satellite data which are kept permanently on hard disk and their description.

The working directories also contain specially generated look-up tables, color and symbol sets and legend keys, which are designed for the the overlaying and mapping functions used in the overview menu. For example, a special kind of mapping had to developed for the results of the magnetotelluric measurements. The induction arrows that provide the information on the conductivity situation have to be rotated and shifted in the rotation direction.

For data management, like transformation, integration, organization of attributes, and error handling, the GIS specialists obtain the necessary information for their task from the working groups. The development of special data analysis methods requires close cooperation between the GIS specialists and the different scientists.

INTEGRATION OF REMOTE SENSING DATA

Landsat TM as a basic information level

Remote sensing data provide the basic information level in the Andean GIS. More than 30 Landsat TM scenes were processed. The georeferencing of the TM scenes was accomplished by utilizing available maps of different types and at scales varying from 1:500,000 to 1:50,000. In addition, GPS measurements in the field were carried out for additional geometric control.

A georeferenced digital color mosaic of the entire study area was created from the TM scenes (bands 7, 4 ,1 in RGB) with a spatial resolution of 50 m based on maps at

1:500,000. This mosaic is permanently stored in the GIS. The Aeronautical Tactical Pilot Charts at a scale of 1:500,000 were the only base map that is available for the entire region.

The individual scenes with all spectral bands remapped to a ground resolution of 25 m are stored in GIS usable format on CD-ROM or Exabyte. Presently the storage of these data requireds about 12 GB hard disk space in addition to about 20 rewritable magneto-optical disks (594 MB), Exabyte- and DAT-tapes and CD-ROMs as a convenient way for data exchange.

Areas of special interest, like the Salar de Atacama, the Salar de Antofalla or the area around Taltal were georeferenced and remapped to a pixel size of 25 m, using Chilean topographic maps at 1:50,000.

For field work the scientists get hardcopies of their working area at different scales for orientation and a first interpretation of the geological situation. Special enhanced images are prepared for detailed interpretation. The geological interpretation is refined subsequently to the field work; the results can be digitized on-screen and input into GIS.

Digital classification concepts were developed simultaneously with the visual interpretation for an area southeast of the Salar de Atacama with a combination of Landsat, SPOT PAN, and high resolution MOMS data. For the area of the Salar de Antofalla the utilization of SIR-C/XSAR in addition to Landsat and SPOT is investigated.

DEMs from SPOT stereo data

For local neotectonic and morphological investigations, digital elevation models and orthoimages were created from SPOT PAN stereo images.

The generation of DEMs from SPOT stereo data is problematic in this region due to changes occuring in the images of a stereo pair, originating from the often considerable time lag between the dates of acquisition. In the andes, the main problems are snow cover, sand drifts, clouds, and vegetation changes. Such variations in the image content result in major areas within a stereo pair where no image correlation and thus no elevation extraction is possible.

Systems like the forward- and backward-looking stereoscopic MOMS-02 will become an interesting alternative for the future. High quality data of the Andes were already obtained during the MOMS-02 shuttle mission. It is expected that the MOMS-PRIRODA mission from spring 1996 to autumn 1997 will produce a larger quantity of high-quality data.

CONCLUSIONS

GIS functions provide a powerful means for combined visualization of different information layers, enabling the user to conduct contextual interpretation and to "see" previously hidden connections, e.g.:

- Relationship between gravity residual anomalies and the geological structure;
- Relations between seismic centers and the structures at the earth surface;
- Changes in river morphology depending on geology;
- Identification of regional structures from satellite images.

It was possible to visualize the Benioff Zone from the collected data of earthquakes or to point out the location of a concentration of earthquake centers in an interruption of a zone of positive gravity anomalies (area of the Salar del Rincon, Salar de Cauchari and Salar de Pocitos). In this area the volcanic belt changes its trend from NNW to SSE, where it was congruent with the positive gravity anomaly, to SSW.

For the publication of results the scientists of the different working groups use the capability of the GIS to present the data in combination with satellite images as maps or perspective views.

TREND

After the initial development during the last two years, the stuctures and the content of the "Andean GIS" have to be continuously brought up-to-date in order to fulfill its function as a "common link" between the diverse groups of scientists. The main task for the future will be the development of additional applications. As a complementary tool a Meta-Information System (Kremers, 1994) is being developed to serve as an information library about the projects, data, results, literature and cooperating scientists and the progress of the research project.

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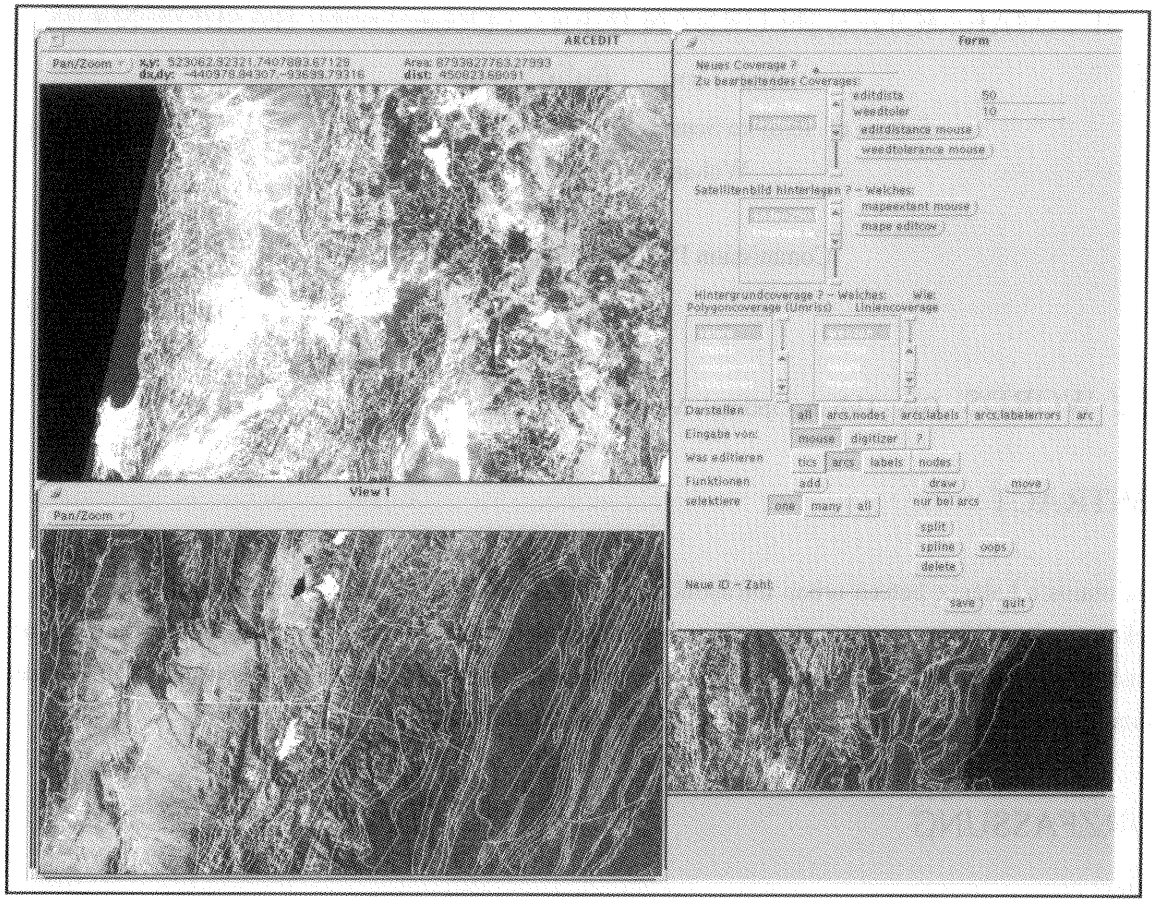

Fig. 3: EDIT menu of the "Andean GIS" fo directly digitizing on satellite images

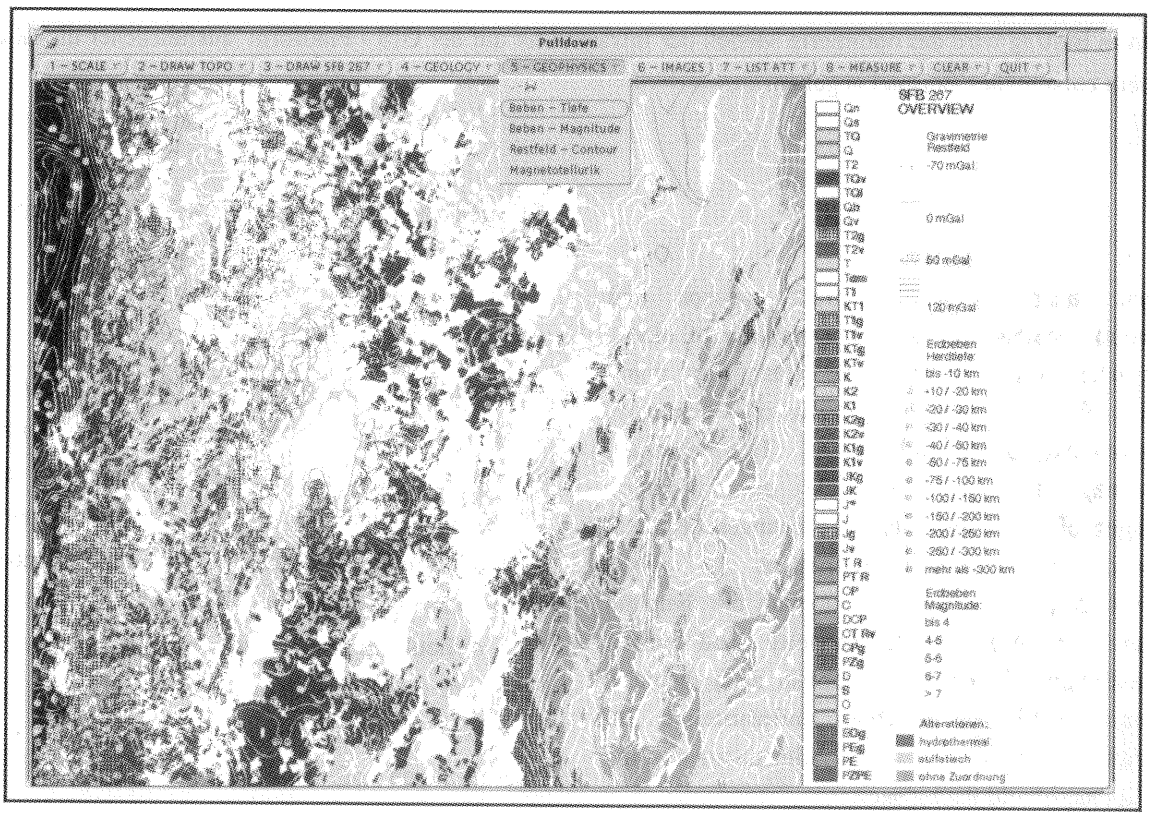

Fig. 4: OVERVIEW menu of the "Andean GIS" for data visualization