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4.4 REGISTRATION AND RECTIFICATION NEEDS OF GEOLOGY*

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Geologic applications of remotely sensed imaging encompass five areas of interest. These include: enhancement and analysis of individual images; work with small-area mosaics of imagery which have been map-projection rectified to individual quadrangles; development of large-area mosaics of multiple images for several counties or states; registration of multitemporal images; and data integration from several sensors and map sources. Examples for each of these types of applications are summarized in Tables 1 - 5.

Individual image work (Table 1) has been primarily applied for medium-scale structural mapping and surface geology delineation. Small-area mosaics (Table 2) have been developed primarily for structural analysis also, but the rectified image can be considered a map product. Both optical (i.e., photographic) and digital rectification and edge matching have been undertaken. Large-area mosaics (Table 3) have been undertaken to provide geologists with regional views that display major tectonic features. Until recently, most of this work has involved digital processing on subsampled Landsat scenes (i.e., a resolution of 200 meters) or optical processing for photomosaics. Temporal processing (Table 4) has been applied to several imaging sensors to detect changes over time associated with vegetation seasonality and of dynamic phenomena such as ocean currents or ice flows. The last area of concern is data integration (Table 5), in which a variety of remotely sensed and ancillary data are map projected and overlain to assist in the analysis of geologic structure. In data integration studies, satellite images form a limited but essential contribution to the overall analysis. As the various data types are being overlaid, the accuracy of image reprojection to a given map projection and scale is of paramount importance.

In summary (see Table 6), geologists have first-order geometry corrections with 1 to 250,000 scale. For the geologists, if you take care of aspect ratio, earth rotation, variable scanning of the mirrors, things you can do automatically, probably 60% of the time that is acceptable. But if geologists are going to do very detailed lithology and lineament mapping, you need to go to ground control points. For satellite ephemeris corrections, we have tried several of those techniques and it never seems to give the accuracy needed, probably because we haven't been able to obtain the ephemeris information for that image. Digital correlation techniques already exist; this is what the MDP is using and now more recently the Purdue and JPL teams are using with FFT techniques. For correction techniques, we look at image to map and image to image. If you go from an image to one map and then another, the geologist may want to convert from a UTM to an orthographic or other projection. This brings out the question: should we really do the Landsat geometry corrections right at the beginning at MDP or should you just supply the coefficient to the user so he can adjust the coefficients if he would really like to map projection 2 instead of map 1. This would reduce having to resample the data twice.

*Edited oral presentation.

One of the things that I feel may still need improvement is the accuracy in the terms of pixels rather than meters. If you are working on a 1:250,000 scale you could get typically with Landsat ±1 or 2 pixels. With the Thematic Mapper, of course, the same distance would be more pixels but now we are going to be working with 1:50,000 and 1:100,000 scale maps, so again the ±1 or 2 pixels will probably be sufficient for the geologist. In other words, if what I am mapping has accuracy within the width of my pencil line, that's all I need. For digital-mozaicking accuracy though, I think that the geologists will complain when they see a mismatch of one pixel, even if it falls within their accuracy criteria from one image to the other. Right away they start worrying that the area of mismatch may be a lineament, and mapping isn't as accurate as it should be. They don't realize that its still within ±80 or 90% of the particular need that they ask for.

We talked a little about band-to-band registration problems. Again, I would like to suggest that maybe somebody ought to investigate the idea of taking the individual bands, trying some of the autocorrelation techniques used to select ground control points, and registering an individual band to your map, and extending your autocorrelation from band to band for further correction. Finally, I mentioned the geometry vs radiometry and topographic displacement. Goddard has its ground control point library, and perhaps they could include some of the new DTM 30-meter topographic data into their correlation? Perhaps this could be added as another data set for topography.

Table 1.

EXAMPLES OF INDIVIDUAL IMAGE WORK

- SAN FRANCISCO PEAKS AREA
  - STRUCTURAL MAPPING
  - SELECTION OF OPTIMUM RATIO COMBINATION BY STATISTICAL METHODS
- DENVER/AUTOLINER PROJECT
  - STRUCTURAL ENHANCEMENT IN DENVER AREA
  - DEVELOP AN AUTOMATIC LINEAR MAPPING TECHNIQUE
- OFFICE OF INTERNATIONAL GEOLOGY
  - SAUDI ARABIA
    - STRUCTURE
    - MATERIAL COVER
  - MOROCCO AND TUNISIA
    - MATERIAL COVER
    - HYDROLOGY

Table 2.

EXAMPLES OF SMALL-AREA MOSAICS (QUADRANGLES)

(DIGITAL AND/OR OPTICAL)

° ALASKA (13 1°x2° QUADS FROM LANDSAT MSS/1974-76)
- DIGITAL MOSAICS
- STRUCTURE AND MATERIALS MAPPING

° GRAND CANYON (4 LANDSAT MSS IMAGE MOSAICS/1978)
- DIGITAL MOSAIC DONE BY NASA/GODDARD
- USGS FLAGSTAFF DID THE FALSE AND SIMULATED NATURAL COLOR PRODUCTS AFTER ATMOSPHERIC SCATTERING CORRECTIONS
- MOSTLY OVERVIEW OF THE CANYON AREA AND FOR COMPARISON WITH TOPO MAP

° 1:250K SAUDI QUADS (10 1°x2° QUADS FROM LANDSAT MSS/1979-80)
- DIGITAL MOSAICS
- STRUCTURAL MAPPING
- BLACK AND WHITE BASE MAP FOR GEOLOGIC MAPPING

° SONAR (GLORIA SONAR IMAGES OF THE ATLANTIC/1980)
- OPTICAL MOSAIC OF 30-40 TRACKLINES
- DIGITAL MOSAIC OF 3-5 TRACKLINES
- PRIMARILY FOR STRUCTURE; BUT SOME MATERIAL TYPES

° RADAR (AIRBORNE AND SATELLITE/1979-PRESENT)
- G. SCHABER, ET AL (SAN FRANCISCO PEAKS AND DEATH VALLEY)
- WALTER BROWN, ET AL/JPL

Table 3.

EXAMPLES OF LARGE-AREA MOSAICS

(STATES AND/OR COUNTRIES)

° NEVADA (1973-74)

- 32 LANDSAT MSS IMAGES
- DIGITAL

° SAUDI ARABIA (1978-81)

- 260 LANDSAT MSS IMAGES
- OPTICAL MOSAIC OF DIGITALLY PROCESSED IMAGES
- STRUCTURE AND BLACK AND WHITE BASE MAP

° FLORIDA

- APPROXIMATELY 15 LANDSAT MSS IMAGES/USGS-RESTON
- OPTICAL MOSAIC

° ARIZONA

- APPROXIMATELY 20 LANDSAT MSS IMAGES/JPL
- DIGITAL MOSAIC

° NORTH AMERICA PLATE MOSAIC (NAM)

- PROPOSED PROJECT OF APPROXIMATELY 2200 LANDSAT MSS IMAGES
- DIGITAL/OPTICAL/HYBRID
- STRUCTURE PLUS HIGH-QUALITY DIGITAL MOSAIC DATA BASE

Table 4.

EXAMPLES OF TEMPORAL PROCESSING

° LANDSAT MSS

- FLAGSTAFF AREA - MONITOR/DETECT VEGETATION CHANGES FOR SOILS TYPE INFORMATION AND SOIL EROSION
- C. ROBINOVE ET.AL. - ALBEDO MONITORING IN ARID LANDS (REGISTERED APPROXIMATELY 20-25 LANDSAT MSS IMAGES)

° RADAR/SEASAT

- ASCENDING VS DESCENDING ORBITS FOR GEOMETRY AND TOPOGRAPHIC INFORMATION BASED ON VIEWING DIRECTION DIFFERENCE
- SEA-ICE DYNAMIC AND ICE-FLOE TRACKING

° HCMM

- OCEAN PATTERN AND LAND AREAS
- THERMAL INERTIA MAPPING (K. WATSON AND A. KAHLE, ET.AL.)

Table 5.

DATA INTEGRATION (MULTI-SENSORS AND MULTI-MAP SOURCES)

° REDWOODS PROJECT (1976-77)

- DIGITIZED COLOR U-2 FOR ENHANCEMENTS AND VEGETATION ... MAP
- GEOLOGY MAP
- PROXIMITY MAP
- TOPO/SLOPE MAP

PURPOSE: GENERATE A DERIVATIVE MAP THAT REPRESENTED THE LANDSLIDE/EROSION POTENTIAL BASED ON THE INTEGRATED DIGITAL DATA SETS.

° CEMENT FIELD (1979-80)

- GAMMA-RAY SPECTROMETRY - 4 PARAMETERS
- AEROMAGNETICS
- MULTI-FREQUENCY RESISTIVITY
- GRAVITY
- LANDSAT MSS
- COLOR U-2
- GEOLOGY
- TOPOGRAPHY

PURPOSE: EVALUATE VISUALLY AND STATISTICALLY THE CORRELATION AMONG THE MEASURED VARIABLES OVER A KNOWN SURFACE AND NEAR-SURFACE GEOCHEMICAL ALTERATION PATTERNS. IN THE STUDY AREA USED, ANOMALOUS GEOCHEMICAL AND GEOPHYSICAL SIGNATURES HAD BEEN PREVIOUSLY DOCUMENTED. IT WAS AN AREA WHERE HYDROCARBON MICROSEEPAGE HAD INDUCED THE ALTERATIONS.

TABLE 5.(continued)

- OCEAN BOTTOM DATA SET (FAMOUS AREA/1980-81)
  - BATH
  - MAGNETIC
  - GRAVITY
  - PRESENTLY ADDING SONAR
- MULTI-SENSOR
  - MSS/SEASAT
  - MSS/RBV
  - FUTURE - MSS/RBV/TM/SPOT

TABLE 6 .

SUMMARY

- VARIOUS TYPES OF GEOMETRIC CORRECTION TECHNIQUES EXIST
  - FIRST-ORDER CORRECTION (I.E., AUTOMATIC CORRECTIONS ONLY)
  - GROUND CONTROL POINT (GCP) CORRECTIONS
  - SATELLITE EPHEMERIS CORRECTION
  - DIGITAL CORRELATION TO ALREADY CORRECTED IMAGE

- CORRECTION TECHNIQUES CURRENTLY IN USE
  - IMAGE TO MAP
  - IMAGE TO IMAGE
  - IMAGE TO MAP 1 TO MAP 2

- IMPROVEMENT IS STILL NEEDED IN THE FOLLOWING AREAS
  - ACCURACY VS COST
  - BETTER EPHEMERIS DATA FOR MORE ACCURATE CORRECTION
    - THIS WILL GREATLY IMPROVE THE USE OF THE IMAGES BECAUSE MORE AUTOMATIC AND EASIER TO USE IN MOSAIC
    - AN ABSOLUTE MUST FOR SEA-ICE MONITORING TYPE PROJECTS
  - MULTI-SENSOR AND MULTI-RESOLUTION DATA INTEGRATION
  - NEED A GOOD FRONT END (I.E., RECEIVING STATION) GEOMETRY CORRECTION TO GET GOOD IMAGE-TO-IMAGE MATCHING FOR DIGITAL AND/OR OPTICAL MOSAICS. CURRENTLY THE COST PER IMAGE FOR A GOOD DIGITAL MOSAIC IS FROM $800 TO $2500 PER IMAGE; NEED TO GET THIS DOWN TO $200

- ACCURACY
  - DEPENDS OF THE RESOLUTION/PIXEL SIZE OF THE IMAGE BEING USED
  - GENERALLY FOR VISUAL INTERPRETATION ±1.5 PIXEL ACCURACY IS SUFFICIENT (I.E., WIDTH OF A PENCIL LINE AS GORDON SWANN WOULD SAY)
  - FOR DIGITAL MOSAICS THE ACCURACY NEEDED IS MORE LIKE ± 0.5 PIXEL

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