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NSG 5014

"AN INVESTIGATION OF AGRICULTURAL AND OTHER EARTH RESOURCE PARAMETERS USING LANDSAT AND OTHER REMOTE SENSING DATA"

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Semi-Annual Status Report

January 1 to June 30, 1977

E7-10213
CR-154797

Dartmouth College
Hanover, NH 03755

Principal Investigators:

Robert E. Huke
Vincent M. Malmstrom
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Richard W. Birnie
Richard E. Stoiber

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David T. Lindgren

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(E77-10213) AN INVESTIGATION OF AGRICULTURAL AND OTHER EARTH RESOURCES PARAMETERS USING LANDSAT AND OTHER REMOTE SENSING DATA Semiannual Status Report, 1 Jan. - 30 Jun. 1977 (Dartmouth Coll.) 24 p G3/43

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SEMI-ANNUAL STATUS REPORT - NSG 5014 - JUNE 30, 1977, Dartmouth College

The Dartmouth LANDSAT Research Group, working in collaboration with the Goddard Institute for Space Studies staff, continued the study and analysis of LANDSAT data together with appropiate field information (ground truth). Technical development continued to improve use of the available data processing devices, especially the RAMTEK display. A user's manual was completed.

1. Agricultural Crop Studies (Prof. Huke)

Without graduate degree candidates or full-time research assistants, the principle technical efforts in this area of interest have been ad hoc undergraduate student projects which result in limited, in-house reports or execution of specific tasks undertaken at the request of GISS staff.

a. Some effort has been applied to the data available on the contents of the entire 9000 acre TWIST Plantation, but no conclusive results are available. However, aerial photos, 512 channel spectrometer data, LANDSAT data and much ground truth are on file for analysis.

b. Considerable effort by several different students was put into the so-called Illinois (Peoria) Project, in an attempt to classify corn and soy crops from LANDSAT data. Although a number of different approaches were made to this problem and many aspects of the solution were examined, it remains an open-ended project.

c. A number of short student projects have been accomplished in the field of agro-meteorology with Professor Malmstrom.

2. Forestry (Prof. Huke)

Emily Bryant is the principal researcher working in association with Gibb Dodge, RC & D Area Forester with the Cooperative Extension Service, University of New Hampshire, based in Conway, NH and with and undergraduate assistant. The goal is to use computer classification of LANDSAT data to make a product useful to the field forester.

The main thrust of our work this half year has been a cooperative project with Seven Islands Land Company in Bangor, Maine. We developed classifications of three Maine townships, and compared the acreages of softwood, mixed wood, and hardwood generated with those from a standard inventory that Seven Islands is having done. The first classification, using "rational signatures" yielded acreages different enough from the inventory that the results would not be useful to Seven Islands. We then revised the classification so there was agreement in acreages in a test township, and applied it to two adjacent townships. There was close agreement in one township and quite a difference in the other. We believe the difference is due to the large amount of timber harvest in the township. We are now in the process of

extending the classification over 19 additional townships - about 500,000 acres total - to see if the discrepancies balance out over a larger area. We have had cooperation, constructive criticism and enthusiasm from Seven Islands on this project. An idea which seems strong to both them and us is an overall forest information scheme integrating standard inventory techniques such as aerial surveys with potential techniques such as LANDSAT classifications and computer displays of information.

We have also been working with classification of clearcut areas - locating training, test, and applications areas, and gathering ground truth for them through overflights of the areas and contacts with the companies doing the cuttings. Aerial photos of the areas will be flown in July.

Bryant and Dodge attended the symposium on remote sensing sponsored by ERIM (Ann Arbor), and found it fruitful in ideas and contacts with other people in the field. One concrete idea we gained there and put into action here was making color printouts of mapped LANDSAT data by using colored ribbons on our printer.

As part of a computer course here at Dartmouth, DTSS was programmed to classify sample LANDSAT data using four algorithms.

Preliminary work on spruce budworm detection showed that we need more ground truth to proceed.

While doing classifications, same area - two different passes - we found a discrepancy of about 1.3% in pixel location between the passes. This is enough to foul us up somewhat.

We have been using the "polygon program" which enables us to have the computer count pixels within the Maine township boundaries - this is a great improvement over previous techniques.

We gave two remote sensing lectures at UNH and two at Dartmouth, and made a display for a workshop for foresters in Hillsboro, NH. A paper has been accepted for a workshop sponsored by the Society of American Foresters (abstract attached - Enclosure 1), to be held in Tuscon, Arizona, next January and one was published in the Mt. Washington Observatory News Bulletin (also attached - Enclosure 2).

3. Land Use (Prof. Huke and Advisor, Prof. Lindgren)

The principle effort in this area is by undergraduates doing limited part-time projects. These projects have provided the basis for an analysis of a combination of LANDSAT data and ground truth (aerial photos) for the New Haven, Connecticut urban area which has been a subject of study in the Geography Department for some time. These results were scheduled to be presented at the Symposium on Machine

Processing of Remotely Sensed Data at Purdue in June but an unfortunate accident to Professor Lindgren prevented completion of the presentation and his attending the conference. However, this material has been organized as background for possible future student projects, particularly for the application of LANDSAT-C data in the coming year.

We have also cooperated with Dr. Paul E. Bruns of the University of New Hampshire and associates who has analyzed changing land use patterns in the Dover, New Hampshire area, using LANDSAT data and aerial photography. This work was reported in the local press (Valley News Story, 17 March 1977 - attached - see Enclosure 3) and will be the subject of a technical report at a later date.

4. Water Quality (Profs. Reynolds and Drake, Graduate Research Assistant McGirr)

Spectra has been obtained from Lake Powell, and Green and Round Lakes, NY. The latter are known calcite precipitating lakes, and their spectra show interesting similarities with those from Lake Powell. We are in the process of analyzing these spectra, and those from Lake Tahoe and Lake Champlain, in order to develop a qualitative discriminator for calcite precipitation in hard water lakes.

The analysis will be made using spectra stored in the Dartmouth Time Sharing System. McGirr spent the winter term retrieving these spectra from GISS and transposing them to the Dartmouth system. The data transfer was completed at the end of the spring term (May 1977). We anticipate early completion of the analysis and publication of the results soon afterward, unless the findings prove trivial.

The earlier work by Carolyn Merry on "The Correlation and Quantification of Airborne Spectrometer Data to Ground Turbidity Measurements at Lake Powell, Utah" (Masters Thesis Sept 1976) has now been published as US Army Corps of Engineers CRREL Report, October 1976.

5. Mineral Resources (Prof. Birnie, Research Asst. Hutton and several undergraduate assistants)

A. Reflectance Spectra of Vegetation Growing on Mineralized Ground

Data presented at the Fall 1976 G.S.A. meetings by Birnie and Hutton showed that spectra collected and averaged within a mineralized zone differed from those collected and averaged outside of the mineralized zone. The spectral difference is concentrated in the 0.67 μ region of the reflectance spectra and is clearly manifested in a channel by channel ratio plot of "mineralized/nonmineralized" spectra. Collection of these averaged spectra required prior knowledge of where the mineralized ground is located.

Since December, 1976 progress has been made in discriminating mineralized vs nonmineralized ground without prior knowledge of the geology. The procedure involves 4 steps:

1) isolation of uniformly dense tree spectra with a rejection of spectra contaminated by grass, roads, etc. This is accomplished by a discriminant in the 0.67 μ region of the spectra.
2) separation of dense tree spectra into shaded and sunlite categories. This is accomplished by a discriminant in the 0.79 μ region of the spectra.
3) separation of mineralized and nonmineralized spectra for each of the groups of shaded and sunlite spectra. This is accomplished by a discriminant in the 0.67 μ region of the spectra.
4) recombining of shaded and sunlite spectra and making a map showing regions of mineralized and nonmineralized spectra.

This work which was done using spectra obtained with multi- channel spectrometer flown in an aircraft, provides a basis for recommendations concerning preferred spectral characteristics of satellite sensors and possible methods of applying existing and future LANDSAT data to mineral exploration.

A paper on this work is in preparation and early publication is anticipated.

B. Reflectance Spectra of Exposed Hydrothermal Altered Rock surfaces using LANDSAT Data (Prof. Birnie, Graduate Research Asst. Dykstra)

A computer analysis of LANDSAT data from the Chagai Hills area of Pakistan has been undertaken.

A field visit was made by Jon Dykstra to the Chagai Hills on October-December, 1976 to obtain preliminary geologic ground truth necessary for the computer study.

As part of the computer study, Dykstra has developed a modified classification algorithm, based on principal component analysis, for processing the LANDSAT data applicable to the detection of possible copper-bearing areas. This part of the work will be reported at the Geological Society of America Annual Meeting in Seattle, November 7-9, 1977 (abstract attached - Enclosure #4).

(A further visit to Pakistan is planned by Birnie and Dykstra - to be funded by the National Science Foundation - during the late summer 1977, to check out on the ground various anamolies which have shown up in the geologic maps in the classification work.)

C. LANDSAT Satellite Mapping of Ultramafic Rocks (Prof. Stoiber and Graduate Research Asst. Carlson)

Work involving the detection of ultramafic rocks - usually associated with copper ore - using LANDSAT data, in Guatemala and Costa Rica was reported at the 5th Reunion of Central American Geologists in Managua, Nicaragua, on 24 February, 1977 (Abstract attached - Enclosure #5).

Work continued in mapping the Oman ultramafics and in refining a statistical signature definition and mapping procedure. The existence of gossan over massive pyritic copper deposits was learned from a mining company operating in the area, and definition of these gossans with the satellite data will be attempted. Separation of ultramafic rocks from others in the area has been very successful and in connection with these studies, Carlson has developed an improved algorithm for application of LANDSAT data analysis to these specific geologic problems and perhaps in other fields. (This improvement is being reported at the Pecora Symposium, Sioux Falls (ND), October 30 - November 2, 1977 (abstract attached - Enclosure #6) and at the GSA Annual Meeting, Seattle, November 7-9, 1977 (abstract attached - Enclosure # 7).

6. Remote Sensing of Volcanic Emissions (Prof. Stoiber, Research Asst. Bratton and Graduate Research Asst. Malinconico)

The Dartmouth research group working on remote sensing of volcanic emissions continued its analysis of data obtained earlier from volcanoes in Central America, Italy, Sicily, Hawaii and continued modification and tuning of instruments (SO_2 and HCl sensors) to make them more field-worthy.

Work concerned with the Central American volcanoes was reported at the 5th Reunion of Central American Geologists, Managua, Nicaragua, 24 February 1977 (abstract attached - Enclosure #8).

Part of this work was also incorporated in the Masters Thesis of Richard W. Hazlett, Dartmouth College, June 1977 "Geology and Hazard of the San Cristobal Volcanic Complex, Nicaragua" which utilized remotely detected data (SO_2) by the project COSPEC. In addition, Malinconico is conducting a study of lava flow patterns as depicted by LANDSAT data to supplement and improve volcanic maps developed by Hazlett.

In March 1977, Stoiber, Bratton and Malinconico undertook further field tests of the COSPEC and GASPEC in vicinity Mt. Etna, Sicily. An important discovery is the problem of dependence on the geometry of sight lines for the reception of SO_2 spectral data. HCl (GASPEC) sensing has not been satisfactory and the machine is still being analyzed. (Trip Report attached - (Enclosure #9).

Bratton field tested the COSPEC in Alaska in April 1977 but results were inconclusive and warrant further comparison with airborne detection data obtained by a University of Washington party.

Progress is underway on developing a small, remote controlled aircraft sampler for providing simultaneous air sampling data in coordination with COSPEC/GASPEC tests.

At the present time, concentrated work on bringing the GASPEC (HCl) instrument to acceptable stability and sensitivity is planned as well as a further visit to Mt. Etna summer 1977.

SATELLITES FOR PRACTICAL FOREST MAPPING?

by
A. Gibb Dodge
RC & D Area Forester
and
Emily Bryant
Dartmouth College &
Goddard Institute For Space Studies

After World War I, forest managers began using aerial photos as a supplement to cruising in gathering forest information. Since then, aerial coverage has proved itself an essential part of forest inventory. Once more, we have a new source of forest information - satellite data. We believe that computer classification of satellite data can fit into forest inventory systems as aerial photo interpretation has.

Two satellites, LANDSAT 1 (launched in 1972), and LANDSAT 2 (launched in 1975) record the earth's reflectance acre by acre from a height of 550 miles. They transmit the data to earth where it is put on computer-compatible tapes. Since different land cover types usually reflect differently, we can train a computer to read the tapes and recognize land cover types by their reflection. A computer printout of the satellite data gives a 1:24,000 scale map classifying each acre into one of up to 30 categories.

As a test, Seven Island Land Company, Bangor, Maine, agreed to compare detailed traditional forest inventory data on three townships (57,955 acres - 23, 454 hectares) under their management with acreage tallies and maps derived from computer classification of data from LANDSAT 1 (scenes 5480-14043 and 5444-14073). Digital maps including three forest categories, water and open area were produced using techniques developed earlier in northern New Hampshire by Dartmouth College, Goddard Institute for Space Studies, and Cooperative Extension Service, University of New Hampshire. Aerial photography and an overflight of the three townships in Maine provided us with ground truth.

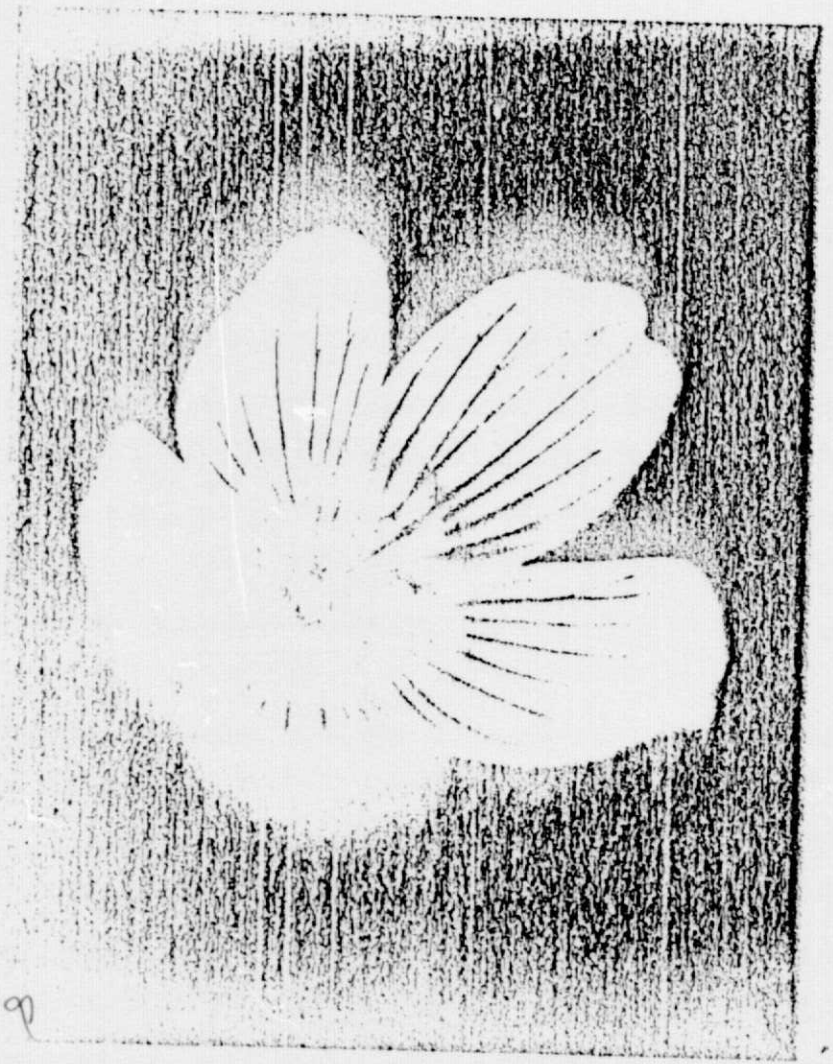
Preliminary comparison of satellite data with Seven Islands Company data indicates that satellite data consistently underestimates softwood forest type. Additional analysis and collaboration with Company forest managers will make LANDSAT digital maps more useful in measuring and locating general forest types for tax purposes in the test area.

(For presentation at Integrated Inventories of Renewable Natural Resources Workshop, January 1978, Tucson, Arizona.)

Enclosure #1

Mount Washington Observatory

News Bulletin



Vol. 18 No. 2

June 1977

a county. Costs for Cheshire County totaled approximately one cent per acre. Once the signatures are made, they appear to be applicable to a number of counties with resultant savings in cost per acre.

Other items of interest appeared while statistics for Coos and Cheshire Counties were being produced: 1. Recent clearcuttings as small as 10 acres can be identified. 2. Field data from 230 plots at the Second Connecticut Lake test area verify that differences in hardwood percentage correlate with differences in computer categories. 3. Through signature refinement, it may be possible to map more detailed forest types such as spruce-fir, white pine-hemlock or aspen. 4. Water bodies of five acres or more are easily identified. Open land of approximately the same minimum size is often identified. Both features serve as control.

In application, LANDSAT data offer objective, timely, and potential low-cost location and measurement of general forest types, and may have immediate field application in recording forest types for tax purposes. At least two northeastern states have forest tax laws based on productivity. Maine and New Hampshire put softwood at high-range valuations.

Frequent updating of changes in the forest, both man-made and natural, must be recorded and taken into account when making management decisions. Traditionally this kind of repetitive coverage has been precluded by high cost, lack of manpower, or lack of time. Computer classification of LANDSAT data may make it feasible. □

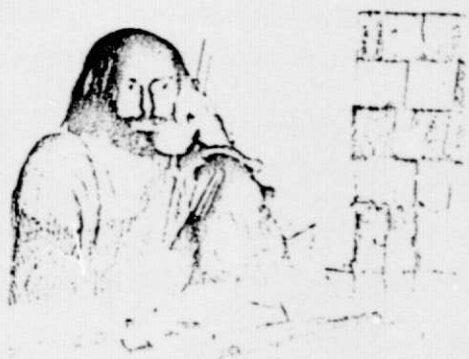
Arthur "Gibb" Dodge is Resource Conservation and Development Area Forester with University of New Hampshire Cooperative Extension Service, headquartered in Conway, N.H. His responsibilities include providing forest land management advice, information and education to private forest landowners in the North County RC&D Project Area — Belknap, Carroll, Coos and Grafton Counties. Emily S. Bryant is principal researcher in forests and related vegetation, Earth Sciences Dept., Dartmouth College, Hanover, N.H., and Goddard Institute for Space Studies, New York, N.Y. She has been active in developing methods of applying satellite data in forest management since 1974.

BUT, SIR ...

Alan A. Smith

Reaching the top of Mount Washington ain't easy, even by telephone. The reason is that good old Gorham 01 cannot be dialed directly - your fingers cannot do the walking for you. And since it now appears that condition will last for another year, we offer this do-it-yourself survival kit for those of our members who may wish to talk with the Guy, or guys, on top.

First, let it be noted that almost all New Hampshire telephone operators are well aware that, to reach Gorham 01, you must go through Littleton,



Driving home a point on Gorham 01. [Lingel]

FOREST TYPE MAPPING WITH SATELLITE DATA

Arthur G. Dodge, Jr., and Emily S. Bryant

The launch of earth-orbiting satellites, LANDSAT (Earth Resources Technical Satellite) 1 and 2 (1972 and 1975), created a new source of earth resources information. There has been much speculation about application of the satellite data to natural resource inventory and land management. The possibilities in forestry are well documented, with recent successes in mapping timber and forest fires, and in range management.

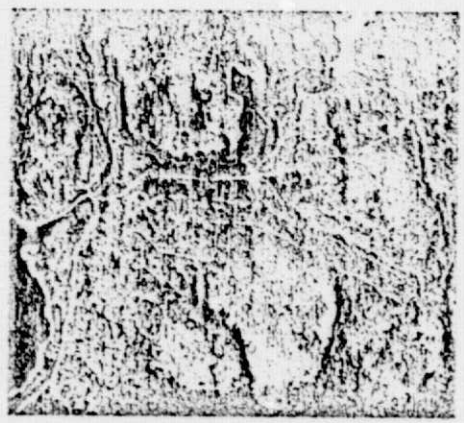
Representatives of the Goddard Institute for Space Studies, Dartmouth College, and the New Hampshire Cooperative Extension Service are cooperating to use LANDSAT data for forest mapping in New England. The research is supported by a NASA grant. Our goals are to: 1. Take advantage of objectivity, speed, and low cost of computer classification of readily available LANDSAT data; 2. Locate and measure forest types, regeneration areas of clearcuts, access roads, wildlife habitat, water, open land, areas of forest stress, and any other related features important in land management.

Thus far we have produced generalized forest type maps of Coos and Cheshire counties in New Hampshire. Computer-measured acreages of hardwood, softwood, and total forested area are within 10 percent of U.S. Forest Service statistics.

We used the digital spectral data from a single LANDSAT pass on July 24, 1973. The basic procedure was to: 1. Choose a training site, an area of known species and forest conditions, within the LANDSAT coverage and identify signatures, its characteristic reflection recorded in four spectral bands by LANDSAT, for forest and other cover types. 2. Apply the signatures to a test area. 3. Apply the same signatures to an entire county to determine the acreage of hardwood and softwood types.

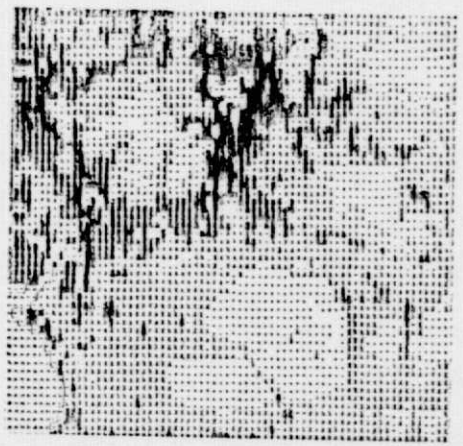
A good training site, used to develop a computer classification of signatures, must include representative forest types, have ground truth available, and be near identifiable water bodies or other features that can serve as map control. Knowledge of forestry and regional conditions is essential in selecting the site, in evaluating computer classifications, and in field checking.

We selected three sites, accessible for field checking: in northern New Hampshire, 5,000 acres in the Dartmouth College Grant; in Cheshire County, 1,300 acres in Annett State Forest; and 2,600 acres in Andorra Forest. Forest type and land-use maps of several scales, black and white aerial photography (1:20,000), color aerial photography (1:12,000), and U-2 color infrared aerial photography (1:130,000) served as ground truth.



Vertical aerial view, Second Connecticut Lake region.

Using overlays of the ground truth information, which conformed to the general scale of the computer printout of LANDSAT data, we located and verified areas of forest types in the training site. We chose a sample of about a dozen pixels (the smallest picture element recorded by LANDSAT, represented by one digit on the computer classification, with an approximate dimension of 57 m x 79 m., about 1.1 acres on the ground) in each area of verified type and averaged the reflected energy values in each of the four spectral bands. These bands, referred to as 4, 5, 6 and 7, are, in microns, 0.5-0.6, 0.6-0.7 (visible green and red), 0.8-0.8, and 0.8-1.1 (both near infrared). The four band averages make up signatures of the forest types.



Computer classification of forest types in mapped area.

Using the signatures, we ran supervised classifications of the training site and adjusted spectral parameters until the computer classification matched ground truth. A supervised classification is one where the operator establishes a computer category defined by a signature and by parameters controlling the spectral boundary around the signature. The computer then determines those pixels whose reflectance is within the boundary and includes them in the category. A classification may include several categories, such as water, fields, forests, built up areas.

A test area should be larger than the training area to amplify any misinterpretation of signatures, and independently obtained forest statistics permit correction of the interpretation. The test area in Coos County was the Second Connecticut Lake Region (15,000 acres) with statistics calculated from a forest type map. As a southwestern New Hampshire test area, we selected Sullivan County (340,000 acres) and used U.S. Forest Service statistics.

While the Forest Service statistics divide New Hampshire forests into two types, hardwood and softwood, our computer classifications used more and different categories: in Cheshire County, softwood, mixed wood, hardwood; in Coos County, dense spruce-fir, less dense spruce-fir, spruce-fir-hardwood, hardwood-spruce-fir, hardwood.

Computer measurements in both Cheshire and Coos Counties compare favorably with Forest Service statistics. Lower total forest area in Coos County may be attributed to pixels not recognized by the computer as belonging to any of the specified categories. In Cheshire, the discrepancy in ratio of hardwood type to total forested area may be caused by the broadness of the three computer categories used there. Narrow categories may minimize errors in interpretation.

Field examination and analysis can further refine interpretation of present categories. We have found that computer classification can give us more detail than currently available regional forest statistics. Developed signatures seem to distinguish 50-50 percent from 75-25 percent and 25-75 percent mixtures of soft and hardwood.

Given the appropriate computer software, costs for developing signatures are on the order of 250 manhours, $1000 for aerial photography, and 30 computer minutes; an additional 50 manhours and three minutes computer time are used in compiling statistics for

3/77

Valley News — Lebanon, N.H

Orbiting Satellites Relay Data To UNH Study Of Land Use

DURHAM — Seeing the forest despite the trees is no problem for Dr. Paul E. Bruns, professor of forest resources at the University of New Hampshire.

He "sees" not only the whole forest but a good part of New Hampshire as well.

Bruns' "eyes' are camera lenses in two satellites orbiting the earth 560 miles high. His study of changing land use in New Hampshire is explained in a recent issue of "Research-Highlights," a publication of the New Hampshire Agricultural Experiement Station.

He says that remote sensing, or the gathering of information from a distance, has many practical applications in agriculture, engineering, forstry, planning and resources. He points to the city of Dover as an example.

This 18,000-acre community has added 1,128 acres t opublic service use and 398 acres to industrial and commercial applications during the past 20 years. At the same time, agricultural, forested and open land have declined.

If you think you might show up on one of Prof. Bruns' pictures, don't worry about it. Remote-sensing satellites don't take photographs with film in a regular camera.

Instead, images are received electronically like a TV picture. Bruns explains that the satellite examines, with its solar-powered sensors, about one acre of the earth at time. Four different wavelengths of light are detectedandthe information is beamed to ground stations to be recorded on magnetic tape.

Bruns uses programs and computer facilities of the Goddard Institute for Space Studies in New York and a terminal at Dartmouth College to recognize what is on the ground through analysis of the electronic signals.

The information gathered electronically is useful only when Bruns relates it to what he already knows about the area "photographed" He chose the Dover area to study because he already had extensive information on it from his earlier aerial photographs and from his ground observations.

In this way he can relate the electronic data to trees, parking lots, buildings, bare ground, water and other physical features of the earth. With this backlog of information, it will be possible in the future to spot the effects of land use changes even before they can be seen on the ground.

Detects Changes

The two remote-sensing satellites now orbiting the earth are called LANDSAT (for Land Satellite) I and II. They pass over every part of the earth once every nine days. Bruns says there will soon be a third satellite called SEASAT which will examine changes occurring in the oceans.

Bruns is quick to point out that the new satellite technology has not entirely replaced aerial photography as a tool for his work. Airplanes are still used but they often fly higher, at 80,000 feet, and take infra-red pictures as well as the conventional black and white photos.

Infra-red photography is especially useful for detecing the green plant pigment, chlorophyll. Any changes in the chlorophyll of plants caused by diseases, insects or environmental stress can be readily seen by the infra-red camera, sometimes before they can be seen by the naked eye.

Healthy plants appear red on infra-red film but unhealthy plants and areas without plants appear gray.

Other Uses

Bruns points out, "Information gathering is just one aid in problem solving. Some day we may have a state-wide operation that gives current information on changes in land surfaces, air water and plants. Examples are snow mass, logging operations and disease and insect infestations in forests and crops."

The researcher is convinced that this kind of information-gathering will pay off and is developing a remote-sensing laboratory at UNH to carry on the work.

"All this will be needed," he says, "if New Hampshire resources are to be used in the most efficient manner and to ensure that there will be resources left for future generations."

FOR SALE

Enclosure #3

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ABSTRACT FORM

Exact format shown on instruction sheet must be followed.

CLASSIFICATION
You must specify one. If more than one category is appropriate, indicate your order of preference by numbers. Be specific.

GEOLOGIC APPLICATIONS OF COMPUTER PROCESSED LANDSAT DIGITAL DATA; CHAGAI HILLS, BALUCHISTAN, PAKISTAN

DYKSTRA, Jon D., and BIRNIE, Richard W., Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire 03755

A geologic map of the Chagai Hills has been generated by computer processing of LANDSAT digital data. The classification algorithm, based on principal component analysis, was developed at Dartmouth in collaboration with the Goddard Institute for Space Studies, NY. A principal component vector in the LANDSAT 4-dimensional color space is calculated from the pixels of control areas representing each of the geologic types to be mapped. An unknown pixel is classified as the geologic type whose principal component vector passes closest to it in the color space. A confidence value for the classification of each pixel is calculated. This value increases with 1) the pixel's proximity to the principal component vector and 2) the separation of the different principal component vectors within the color space. Spurious pixel variations due to inhomogenities within a pixel are smoothed by averaging each pixel with its eight contiguous neighbors.

The algorithm was applied to 5000 km^2 of the Chagai Hills. This region is located in the southeastern end of the Mediterranean-Iran copper belt and is a likely porphyry copper setting. Cretaceous andesite flows and pyroclastics are intruded by Cretaceous to Eocene(?) plutons ranging in composition from quartz-diorites to granites. The classification procedure distinguished three rock types (volcanics and two intrusive phases), four unconsolidated deposits, and zones of possible hydrothermal alteration. LANDSAT geologic mapping is especially applicable to the Chagai Hills due to the region's large areal extent, arid climate, well exposed geology, and very limited accessibility.

geochemistry

geology
archeologic
coal
(economic) 2nd
education
engineering
environmental
extraterrestrial
general
history of
marine

Precambrian
Quaternary
structural

geomorphology

geophysics

geoscience information
hydrogeology
mineralogy/crystallography
paleomagnetism
paleontology/paleobotany

petrology
experimental
igneous
metamorphic
sedimentology
sedimentary petrology
stratigraphy
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(OTHER) 1st
Remote Sensing

☐ Oral ☒ Poster ☐ Either

☐ Symposium _____
(title of symposium)

Speaker Jon D. Dykstra ☒ Student paper ☐ GSA Student Associate

I will be available to serve as a cochairman for a technical session on or concerning _____

For correspondence purposes, list address of senior author if different from above _____

Phone numbers and dates where senior author can be contacted (603) 646-3269 Present to Meeting

Geological Society of America Annual Meeting, Seattle, Washington November 7-9, 1977

3/77

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Enclosure #4

To be delivered at the 5th Reunion of Central American Geologists

ABSTRACT

Remote Sensing of Central America Ultramafic Rocks Using LANDSAT Data

by

Gerald G. Carlson
Department of Earth Sciences, Dartmouth College
Hanover, N.H. 03755, U.S.A.

A program of remote sensing of natural resources using digital LANDSAT satellite data has been underway for nearly three years at Dartmouth. One project has involved the delineation of ultramafic rocks in areas of varying climatic conditions. It is well known that in many areas distinctive vegetational anomalies are developed over ultramafic rocks due to the sterility of soils derived from these rocks.

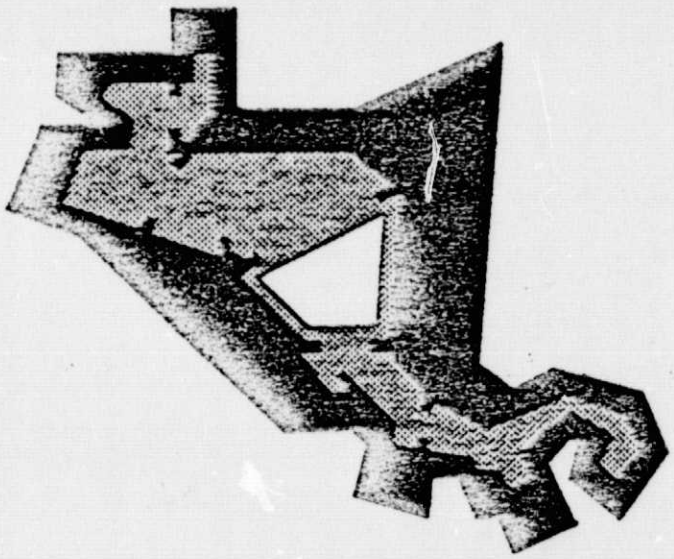
In Central America, ultramafic rocks occur along the Motagua and Polochic valleys in Guatemala and the Santa Elena peninsula in Costa Rica. A distinctive lack of vegetation is evident over many of these known ultramafic exposures. A computer classification of the satellite data over two areas, near Huehuetenango in Guatemala and the Santa Elena peninsula, has shown that it is possible to distinguish most of the ultramafic rocks. Areas of false classification, those which are mapped with the satellite data as ultramafic rocks but are not, include fresh alluvium in river valleys, vegetated alluvium and dry farm fields in areas of arid climate, and fresh, lightly vegetated volcanic flows. Further confusion arises with the Costa Rica example; burning of grassy areas has occurred both on and off the ultramafic rock outcrop just prior to the satellite pass.

5th Reunion of Central American Geologists, Mangua, Nicaragua, 24 Febuary 1977

PROGRAMA

V REUNION DE GEOLOGOS DE AMERICA CENTRAL

20-26 febrero 1977 Managua Nicaragua



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February 24, 1977

20 Neotectónica en el Pacífico Sur de Costa Rica.
Rodolfo Madrigal Gómez — C. R.

40 Generalidades Tectónicas de Nicaragua
Julio Garayar — Nicaragua.

GEODINAMICA

00 Paleomagnetic studies of Cretaceous rock from Honduras; Tectonic Implications.
Welf A. Gose
Douglas K. Swanty — U. S. A.

20 Paleomagnetic studies of Mesozoic rock; Stratigraphic Implications, Honduras.
Wulf A. Gose — U. S. A.

A new investigation of middle América Trech fectonics.
Joel S. Watkings
Creighton A. Burke
40 J. Lamar Worzel
Gary V. Latham
Charles L. Drake
John W. Ladd
Thomas H. Shipley — U. S. A.

Land sat and Sea sat
00 W. R. Carter
R. L. Miller — U. S. A.

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HOTEL INTERCONTINENTAL — MANAGUA

EXCURSIONES

Salida a Ruinas de León Viejo, Campo Geotérmico y Aspectos de la Geología de Nicaragua (San Rafael del Sur).

VULCANOLOGIA Y SISMOLOGIA

Investigation of active faulting in Managua, Nicaragua.
50 G. Brogan,
K. Weaver,
K. M. Cline — U. S. A.,

8:50 — 9:10 Fallas activas de Managua
Julio Garayar Vanez — Nicaragüa

9:10 — 9:30 Active faulting along the Caribbean-North American Plate boundary in Guatemala.
D. P. Schwartz
C. Woodward — U. S. A.

9:30 — 9:50 Eearthquake prediction in México and Central América by the seismicity gap method.
T. Matumoto — Japón
M. Ohtake — U. S. A.
G. Latham — U. S. A.

9:50 — 10:10 REFRIGERIO

10:10 — 10:30 Aftershocks of the Guatemalan earthquake of February 4, 1976.
T. Matumoto — Japón
G. Latham — U. S. A.

10:30 — 10:50 Plans for a national seismic network of Costa Rica.
J. Umaña — C. R.
R. Saenz — C. R.
T. Matumoto — Japón
G. Latham — U. S. A.

10:50 — 11:10 The seismic activity of Volcano Arenal
T. Matumoto — Japón
J. Umaña — C. R.

11:10 — 11:30 Remote sensing of Central América ultramafic rocks using land sat dates.
Gerald G. Carlson — U. S. A.

11:30 — 11:50 Tidal Triggering of volcanic and seismic phenomena in Central América.
Michael J. Carr — U. S. A.

11:50 — 12:10 The seismicity of Northem Costa Rica.
T. Matumoto — Japón
G. Latham — U. S. A.
J. Umaña — C. R.

12:10 — 14:00 ALMUERZO

14:00 — 14:20 Plans for national seismic network for Honduras.
M. Zúñiga — Honduras
T. Matumoto — Japón
G. Latham — U. S. A.

ABSTRACT

GEOLOGIC MAPPING BY COMPUTER ANALYSIS
OF DIGITAL LANDSAT DATA

CARLSON, Gerald G., Department of
Earth Sciences, Dartmouth College,
Hanover, NH 03755

Digital LANDSAT data is applied to geologic mapping at Dartmouth College using an IBM 360/95 computer and software assistance at the Goddard Institute for Space Studies in New York, together with our own mapping algorithm. LANDSAT computer compatible tapes used have been geometrically corrected using Bernstein's method. Maps are printed at an accurate 1:24,000 scale on a high speed printer.

An algorithm has been developed which has two special features: assignment of *SIGNATURE PROBABILITIES* and refinement of pixel classification considering *NEAREST NEIGHBORS*. Four-band signatures are extracted using multiple training sites for each classification category, each site on the order of 25 pixels in size. The four-band reflectance values from LANDSAT are normalized to unit vectors and compared to a standard signature set. The probability of each standard signature representing each training category is calculated. These probabilities are modified by an albedo weighting factor.

The signature reflectance characteristics of a specific rock type typically show a broad variation. This is due to the natural inhomogeneity of the exposed surface, resulting from factors such as weathering, soil cover, vegetation cover and slope direction and angle. This variation, combined with the noise factor inherent in the satellite data, results in a large degree of overlap of spectral characteristics among most

Pecora Symposium, Sioux Falls (ND), October 30-November 2, 1977

Enclosure #6

rock types. To overcome this problem, we re-calculate the probabilities for each pixel within a survey area by averaging it with its eight adjacent neighbors. Root mean square averaging is done to emphasize high probabilities. The final map therefore delineates areas in which there is a high probability of the occurrence of one of the rock types originally chosen as a training category.

The mapping algorithm has been applied to several specific geologic problems with good success in delineating the target features and significant improvement over earlier supervised classification methods. These examples include outlining ultramafic rock exposure in Western Guatemala, mapping members of the ophiolite sequence in Oman and defining the areal extent and relative ages of pre-historic flows from Volcan San Christobal in Nicaragua.

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CLASSIFICATION
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ABSTRACT FORM

Exact format shown on instruction sheet must be followed.

GEOLOGIC MAPPING BY COMPUTER ANALYSIS OF DIGITAL LANDSAT DATA

CARLSON, Gerald G., and STOIBER, Richard E., Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire 03755

Digital LANDSAT data from computer compatible tapes geometrically corrected by Bernstein's method are used for geologic mapping using an IBM 360/95 computer and software assistance at the Goddard Institute for Space Studies, together with our own mapping algorithm. Our algorithm has two special features: assignment of Signature Probabilities and refinement of pixel classification considering Nearest Neighbors. Four-band signatures are extracted using multiple training sites for each classification category. These are normalized to unit vectors and compared to a standard signature set. The probability of each standard signature representing each training category is calculated and modified by an albedo weighting factor. Spectral reflectance characteristics of a specific rock type typically show a broad variation due to weathering, soil cover, vegetation cover, slope direction and angle and noise in the satellite data. This results in overlap of spectral characteristics among most rock types. So, for each pixel in a survey area, we re-calculate its probability of representing each rock type by averaging it with its eight neighbors. Root mean square averaging emphasizes high probabilities. The final map delineates areas with a high probability of occurrence of each rock type chosen as a training category. The algorithm, used to map members of the ophiolite sequence in Oman, successfully delineates ultramafic rocks, mafic flows, older sediments and terrace deposits.

geochemistry

geology
archeologic
coal
economic

education
engineering
environmental
extraterrestrial
general
history of
marine

Precambrian
Quaternary
structural

geomorphology

geophysics

geoscience information
hydrogeology
mineralogy/crystallography
paleomagnetism
paleontology/paleobotany

petrology
experimental
igneous
metamorphic
sedimentology
sedimentary petrology
stratigraphy
tectonics
OTHER
Remote Sensing

☐ Oral ☒ Poster ☐ Either

☐ Symposium Geological Application of Satellite Remote Sensing
(title of symposium)

Speaker Gerald G. Carlson ☐ Student paper ☐ GSA Student Associate

I will be available to serve as a cochairman for a technical session on or concerning

For correspondence purposes, list address of senior author if different from above

Phone numbers and dates where senior author can be contacted (603) 646-2818

GASES AT CENTRAL AMERICAN VOLCANOES

by Richard E. Stoiber, Dartmouth College, Hanover, N.H., U.S.A.

Monitoring of temperatures and gases is continuing at three volcanoes in Central America, San Cristobal and Cerro Negro in Nicaragua, and Santiaguito in Guatemala. The gases are being collected as condensates from which relative amounts of HCl, SO_2 and HF can be determined. SO_2 is also determined by remote sensing using a correlation spectrometer. Remote sensing of SO_2 has indicated a lower rate of emission at San Cristobal since the eruption of March, 1976. Now it is hundreds of tons per day. Then it was thousands of tons per day. In November, 1971, before the present episode, the rate was 360 tons per day, about equal to that in November 1976. Santiaguito which erupts ash about once per hour in clouds which are five hundred to a thousand meters high, produced less SO_2 per day than San Cristobal where no ash is being discharged. Measurements in July 1976 indicated less than 200 tons per day.

The remote sensing data seem to be of sufficient value to warrant consideration of frequent and regular monitoring coupled with monitoring of seismic activity associated with a volcano. Regular monitoring must be carried out by a local organization.

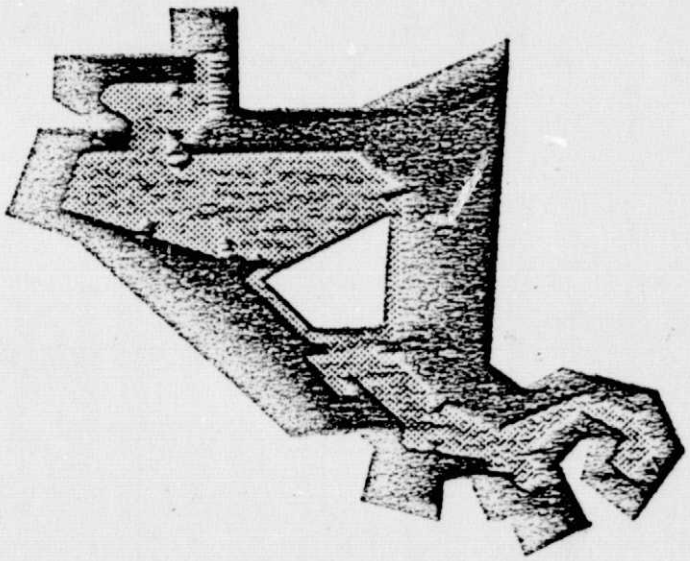
5th Reunion of Central American Geologists, Managua, Nicaragua, 24 February 1977

Enclosure #8

PROGRAMA

V REUNION DE GEOLOGOS DE AMERICA CENTRAL

20-26 Febrero 1977 - Managua, Nicaragua



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14:20 — 14:40	The Choloma earthquake swarm of 1976 T. Matumoto — Japón M. Zúñiga — Honduras
14:40 — 15:00	Effects of the February 4, 1976 Guatemala earthquake (Ritcher magnitude 7.5) on man-made structures surface rupture. D.P. Schwartz — U. S. A. L.S. Cluff — U. S. A. T. Rogers — U. S. A.
15:00 — 15:20	Repercusiones del Terremoto de Guatemala en la República de El Salvador. Maximiliano Martínez — El Salvador.
15:20 — 15:40	REFRIGERIO
15:40 — 16:00	Mapa de Epicentros de Temblores ocurridos en Nicaragua durante el año 1976. Arturo Aburto — Nicaragua.
16:00 — 16:20	Gas from Nicaraguan. Volcanoes Richard E. Stoiber — U. S. A.
16:20 — 16:40	Resumen de la actividad magnética en Nicaragua. Mario Chávez — Nicaragua.
16:40 — 17:20	Observaciones de la actividad volcánica en Nicaragua de 1815 a 1976. Investigaciones Vulcanológicas en Nicaragua. Actividad Microsísmica en el Volcán San Cristóbal. Alain Creusot — Francia (Nicaragua).
	GEOLOGIA ECONOMICA Y MINERA
17:20 — 17:40	Depósitos Minerales del tipo Kuroko, en la América Central. L. J. Buchan — U. S. A.
17:40 — 18:00	Bosquejo Minero de Nicaragua Glen Hodgson V. — Nicaragua
18:00 — 18:20	Bosquejo Minero de Costa Rica Manuel A. Brenes M. — C. R.
VIERNES 25	
8:30 — 8:50	El Contrato Minero de Cerro Colorado, Panamá. Jorge Luis Quiroz — Panamá.
8:50 — 9:10	Prospección Aurífera media de arsénico. Giorgio Recchi — Italia.
9:10 — 9:30	Geología Minera de una pa Montes del Aguacate, C. R. Allan López Saborío — C. R
9:30 — 9:50	Legislación Minera en Cent Orlando Rodríguez Marenco
9:50 — 10:10	REFRIGERIO
	HIDROGEOLOGIA Y GEOTE
10:10 — 10:30	Groundwater Occurance in along the Pacific Coast of North América. Joseph Bar-Joseph — Israe
10:30 — 10:50	Consideraciones sobre el de aguas subterráneas de rilla, y zonas propuestas p Marcelino Losilla Penón —
10:50 — 11:10	Comentarios sobre el map Costa Rica. Daniel Mora Castro — C.
11:10 — 11:30	El Agua Subterránea en Ni Carlos Valle Gutiérrez —
11:30 — 11:50	Métodos para analizar prue en acuíferos con flujo natur Gunther Schosinsky N. —
11:50 — 12:10	Un modelo geofísico, med sistividad eléctrica y refrac nes hidrogeológicos, en Ba (Puntarenas) Costa Rica. German Leandro C. — C.
12:10 — 14:00	ALMUERZO
14:00 — 14:20	Perforaciones geotérmicas (Proyecto Momotombo) Carlos Ferrey O. — Nicara
14:20 — 14:40	Inventario de Recursos Ge Nicaragua. Carlos Ferrey O. — Nicara

PGK

REPORT ON TRIP TO SICILY - March 17-31 1977

(NASA Grant NSG 5014)

Purpose of Trip. To test the remote sensing, HCl instrument. To obtain new data regarding sulphur dioxide emission at Mt. Etna using the SO_2 spectrometer. Field tests were planned on Mt. Etna where the fumes emanating from the summit can be viewed remotely and where the temperature is colder than in Central America. It was believed that this would be an optimum place for observing HCl.

Results*. Mt. Etna was fuming copiously. We measured the HCl with difficulty. The instrument was unstable both electronically and mechanically, but it gave us some data. The best data was obtained by observing the fumes at the crater and poor data were obtained observing fumes some distance from the crater. This was assumed to be because of lower concentrations at greater distances. It is not certain whether these data can be evaluated qualitatively, but general answers can presumably be obtained.

SO_2 measured at several distances from the crater on several days was between 1,300 and 1,900 tons/day. The results were consistent and thought to be good measures of the SO_2 abundance. There was no evidence that SO_2 dissolved in water vapor more extensively at the slightly greater distances at which some measurements were made relative to others. These results compare with the 1975 data of Zettwog, which averaged 3,500 tons/day and the earlier data of Stoiber and Malone which averaged 230 tons/day. The emission of water vapor appeared visually to be very much greater than during the March 1975 visit of Stoiber and Malone. The

* All results are being re-evaluated in the laboratory. The data in this report are simply those acquired from calculations made in the field.

The large change factor of probably 8 times was not surprising. Difficulties in measuring arose from the fact that the plume changed direction rather quickly during the day, sometimes during a single run. It would seem best to visit in a season in which the wind direction was more constant. If indeed meteorological data, which we have requested, indicates that there is such a time of year.

A camera with motor-drive was field-tested for the first time. The time-lapse photography taken with the camera has been sent for development and results will be evaluated.

Future Plans. At present it is planned to check the electronics of the HCl machine in detail to improve its stability and possibly its sensitivity. It is thought that the machine in the summer time could be taken to the summit of Mt. Etna very near the point of emission of the plume and would thus probably find very large concentrations from which, with stable electronics, we could easily calculate tons of HCl emitted per day. The necessity for freezing conditions, which had been postulated as a possible requirement in using this machine, seems to have proven not necessary; a large concentration is the key factor and a stable machine is necessary.

On the same expedition when HCl measurements were made, or perhaps another time one could measure the SO_2. One could also investigate SO_2 emission related to distance from the vent. It appears that the configuration of the roads at Etna is such that with the constant wind direction and velocity one could make several runs per day at different distances from the vent. This

would allow the evaluation of whether or not there is an important amount of the SO_2 dissolving in the water vapor with time. We now await evaluation of meteorological data to determine when would be a most suitable time of year. It is contemplated that this may be used as a Master's degree project. It is possible that Mr. Malinconico will undertake this study.

Richard W. Stoiber