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Oil Exploration Needs for Digital Processing of Imagery*

The oil industry probably purchases more ERTS images than any other commercial group; however, it does not seem to be applying digital processing methods broadly.

Abstract: *Oil exploration employs a variety of remote-sensing methods, but little or no digital processing is applied to the imagery. ERTS imagery is the most promising type for any future digital processing because it is available in digital format and is useful for reconnaissance studies. Some requirements for future processing are: (1) Ready availability of ERTS digital tapes, (2) Access to processing programs and examples, (3) Interactive processing, (4) Rapid and low cost processing on a per-square-mile basis. Processing programs with greatest oil exploration potential are those that enhance the geologic information content for the interpreter.*

Introduction

Digital recording, processing and display of seismic data are widely used in oil exploration. Major oil companies operate their own in-house computer facilities whereas smaller companies use contractor computer facilities. Oil company research organizations are continually developing new processing techniques.

It might be assumed that this technology and motivation would be applied to digital processing of remote-sensor imagery by oil exploration groups. This does not seem to be true, however, based on the following observations:

- Reviews of publications, conferences and symposia concerned with image processing reveal few oil company attendees and even fewer papers directed toward oil exploration. The exceptions will be noted later.
- Discussions with image processing personnel indicate a lack of activity by oil companies. Only one oil company is included in the long list of NASA principal investigators under contract to evaluate data from the Earth Resource Technology Satellite (NASA, 1972, p. M-1).

The oil industry does employ remote sensing as discussed in the following section, so the lack of digital processing activity is related to other factors which are considered later.

Role of Remote Sensing and Image Processing

General

A short discussion of how oil companies typically use remote sensing will give a useful perspective to the subject of image processing. Remote sensing is employed in oil exploration as a regional reconnaissance method used in advance of more expensive detailed methods. In unexplored areas remote-sensing surveys are used to indicate structural trends or anomalies so that the subsequent seismic surveys may be directed toward the more promising areas. Aerial magnetometer surveys, surface gravity surveys, and geologic field work are also conducted in advance of the siesmic work. Many different geological and geophysical methods and personnel are employed before a wildcat well is drilled, and today it is unrealistic to credit an oil field discovery to a single method or individual. For this reason experienced explorationists react with amusement and disdain to press releases announcing "New . . . technology will find oil fields, ore deposits,

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spot crop diseases, etc." The reader can insert any remote-sensing method in the blank space and have a recognizable press release. Such announcements hinder the acceptance of new methods by experienced explorationists.

I have been interviewed by a number of government-funded *cost-benefit surveys* seeking to learn, in terms of dollars, how much our company (or the industry) has gained through using various remote-sensing methods. As pointed out in the preceding discussion, oil exploration is a lengthy and complex process. Attempting to assign a dollar value to a single exploration activity is a futile venture and any estimates are of doubtful significance.

TYPES OF DIGITAL PROCESSING

Following is a partial list of digital methods for processing and enhancing remote-sensor imagery:

1. Cosmetic corrections.
   a. Replace scan drop-outs.
   b. Correct for banding.
   c. Geometric corrections.
   d. Noise removal.
2. High-pass filtering.
3. Contrast enhancement.
4. Spectral ratio images.
5. Edge enhancement.
6. Directional filtering.
7. Spectral classification.
8. Temporal change detection.

This list was originally compiled for ERTS image processing, but many of the techniques are applicable to other types of imagery.

Automatic pattern recognition is not listed as a geologic application for the following reasons. A relatively simple geologic feature, such as a fault, can be expressed in the terrain by dozens of different features or combinations of features. Yet any one of these features would be difficult to describe in a manner suitable for computer memory storage. Also the terrain features may occur but have no association with faults. Terrain scarps, for example, may be associated with faults, but scarps may also be formed by erosion and have no structural significance. The experienced geologist-interpreter can make these distinctions that would be extremely difficult to program into a pattern recognition algorithm.

OBJECTIVE OF IMAGE PROCESSING

In many types of image interpretation, the interpreter knows *in advance* the *targets* or features of interest. A forester may be searching specifically for evidence of bark beetle infestations, or a geographer may be studying rates of urbanization. For these and other applications, specific processing can be applied to the imagery with a high probability of enhancing or classifying the subject of interest. The geological interpreter, however, is generally trying to map and describe the terrain, structure, rock types, and note *anomalies* for further investigation. Because of these general objectives of geologic interpretation, it is difficult to specify which type of image processing will be most useful. Also, for different types of terrain and geology, different processing methods may be needed. For geological interpretation, the ideal image-processing system would be an interactive one. The interpreter could observe the processed image in real-time and submit changes until the optimum information content for his project is achieved.

The image processing should be rapid and able to handle large areas. For competitive and other reasons, it is often necessary to complete the reconnaissance work rapidly. Lengthy delays for data acquisition and image processing will not be tolerated by management. The processing cost per square mile must also be reasonable because this is a preliminary phase in the exploration process.

REMOTE SENSORS EMPLOYED IN OIL EXPLORATION

GENERAL

Table 1 lists the four major types of imaging remote sensors employed in oil exploration, together with comments. This discussion deliberately omits the non-imaging airborne methods, such as magnetic and gamma ray surveys, which are geophysical rather than remote-sensing techniques. The technology and interpretation of the various remote sensors have been presented in other papers and need not be reviewed here. The discussion will focus on the potential benefits of digital processing of imagery for exploration.

AERIAL PHOTOGRAPHY

Aerial photography is the classic remote-sensing method and has long been used in oil exploration. Stereoscopic pairs are studied for detail and mosaics are employed for regional investigations. Little or no digital processing is applied because of the time and cost of digitizing the hundreds of aerial photographs that are required to cover a typical exploration area.

Optical processing using coherent light has been applied to aerial photographs and may have potential for geologic problems such as discriminating fracture systems.

THERMAL-INFRARED IMAGERY

Today thermal infrared imagery is typically recorded quantitatively in analog form

TABLE 1. CHARACTERISTICS OF REMOTE SENSORS EMPLOYED IN OIL EXPLORATION

Image Type	*Wave Lengths*	*Energy Detected*	*Recording Medium*	*Remarks*
Aerial Photography	4-.9μm	Reflected solar	Film	Standard method. B & W Color, IR Color, Stereo
Thermal Infrared	8-14μm	Radiant Thermal	Analog Magnetic Tape	Night time. Temperate to arid terrain
Side-looking Radar	1-4 cm	"Reflected" Microwave	Film	All-weather capability
Earth Resource Technology Satellite	.5-1.1μm	Reflected Solar	Digital Magnetic Tape	Small-scale, regional coverage

on magnetic tape. During playback onto film, the scanner distortion is removed and film density and contrast are optimized (Sabins, 1973). Discrete level slices and digitized temperature values displayed as gray scale or color are processing options. The value of these processing methods has been demonstrated for mapping surface temperature patterns in water bodies (Daedalus Enterprises, Inc., 1974). Geologic applications of these options have not been so convincingly demonstrated, perhaps because the processing technology is relatively new.

SIDE-LOOKING RADAR

Side-looking radar has become a widely used oil exploration reconnaissance technique particularly for jungle terrain with poor weather for aerial photography such as in South America and Southeast Asia. The imagery is recorded directly on film, which again presents the digitizing problem. I am aware of no digital processing that is routinely applied to radar imagery for civilian use.

EARTH RESOURCE TECHNOLOGY SATELLITE (ERTS)

Imagery from the ERTS satellite is being widely used, especially by the oil industry. The *extractive industries* are the largest single user category at the EROS Data Center at Sioux Falls, South Dakota, and account for 39 percent of the imagery orders (W. G. Fischer, personal communication). It may be assumed that oil companies are the major part of the extractive industry group.

In my personal opinion, ERTS utilization would be even higher if the image quality was improved. We routinely order 70-mm black-and-white positive transparencies of the four spectral bands comprising an ERTS image. Without exception, the images have low contrast and a dense gray background. Each image must be photographically enhanced before it can be used. Each such additional photographic process decreases image resolution and increases the cost and time delay for the user. On the positive side, the EROS Data Center apparently is reducing the delivery time for imaging orders.

ERTS imagery is well-suited for exploration reconnaissance because of the broad regional coverage, acceptable resolution, and minimum image distortion. For some regions it is the only imagery readily available. ERTS is the remote sensor with greatest potential for digital processing for the following reasons: (1) imagery is available in digital magnetic tape format; (2) four registered spectral bands are available providing opportunity for spectral ratios and classification; (3) because of small scale, the processing costs per square mile are reasonable. Despite this potential, I understand that only 4 percent of orders at the EROS Data Center are for ERTS digital tapes.

A number of university, government and commercial facilities are developing and applying digital processing methods for ERTS imagery. The list of ERTS Principal Investigators (NASA, 1972) indicates the scope of NASA-funded work. Papers presented at the ERTS Symposia sponsored by NASA in March 1973 and December 1973 give a useful summary of ERTS applications by various disciplines. Digital processing, particularly spectral classification, is extensively used for agriculture, forestry, geography and related disciplines. Most geological investigations, however, treat the ERTS images as aerial photographs and use classical photogeology interpretation methods to annotate features, especially lineaments. Field checks and comparison with available geologic maps are used to evaluate the ERTS interpretations. This is a valid and productive use of ERTS imagery, especially in those areas that lack geological maps. Even in mapped areas, new geologic relationships are revealed because of the regional coverage provided by ERTS.

A notable application of image processing for geologic applications is the work of Billingsley and Goetz (1973) who presented examples of the various digital methods listed earlier in this report. They processed the ERTS digital tapes in order to prepare an optimum image for the particular geologic problem. For example, ratio images were useful for enhancing mineralized zones in Nevada whereas directional filtering emphasized fracture patterns in Arizona.

The ERTS spectral classification programs, which are so useful for other disciplines, may have limited application for oil exploration. The classification routines must deal with surface features, such as vegetation and man-made pattterns, which commonly conceal the bedrock. Image enhancement programs which emphasize the geologic structure and anomalies seem to have highest potential for oil exploration.

Conclusions

For oil exploration, ERTS imagery is the remote sensor with greatest potential for digital processing for the following reasons:

- ⋆ Worldwide imagery is available in digital form.
- ⋆ The small scale, minimum geometric distortion and uniform oblique illumination are optimum for regional interpretation.
- ⋆ Digital image-processing programs now exist that may have petroleum exploration applications.

The oil industry probably purchases more ERTS images from the EROS Data Center than any other commercial user group. This suggests that the oil industry should also be a major potential user of digital processing methods for ERTS. As noted in the introduction, however, the oil industry does not seem to be applying this technology. In order for the industry to make effective use of digital processing, the following requirements must be met.:

- ERTS digital tapes need to be available to users on a timely basis. A delivery time of several months for basic data is often unacceptable.
- Processing programs and examples of their use should be available for analysis by potential industry users. This would avoid wasteful duplication of programming effort and speed the adoption of new methods.
- The interpreter should be able to monitor and interact with the processing operation in order to obtain optimum results for his requirements.
- To be an effective aid in reconnaissance mapping, any digital processing should be rapid and relatively inexpensive on per-square-mile basis.

Some current efforts by university, government, and commercial facilities are directed toward these requirements. Hopefully, the new processing methods will be adopted and applied to oil exploration projects.

I have attempted to answer, to the best of my ability, the editor's request for a survey of oil industry applications of digital image processing. These are my personal observations and conclusions, and I do not purport to speak for my employer or for the oil industry. Undoubtedly some pertinent work has been omitted in the survey, but this was not intentional.

References

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