SUMMARY

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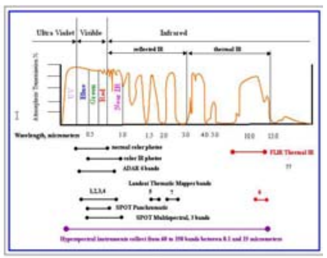
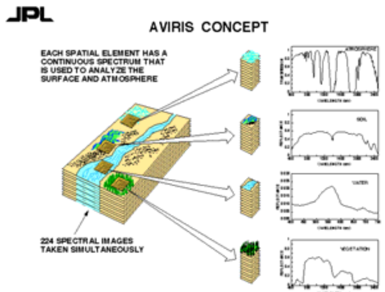
Explorationists evaluating remote terrain can now consider using airborne hyperspectral imaging for detecting onshore oil seeps. Previous to this new technology, the spatial and spectral resolution of sensors was too limited for successful detection of onshore oil seeps. A cooperative R&D project documented the spectral characteristics of seeps and associated oil-impacted soils and constructed a spectral library to enable deployment of the application to other areas. This oil-focused spectral library may be the first of its kind in the commercial sector and includes signatures with varying amounts of oil, tar, vegetation, soils, and rock. This library can be used with other handheld, airborne, and satellite hyperspectral sensors to support both exploration and environmental applications. The experience gained and this library support the use of hyperspectral remote sensing for detecting onshore oil seeps and oil-impacted soils globally.

OVERVIEW OF HYPERSPECTRAL TECHNOLOGY



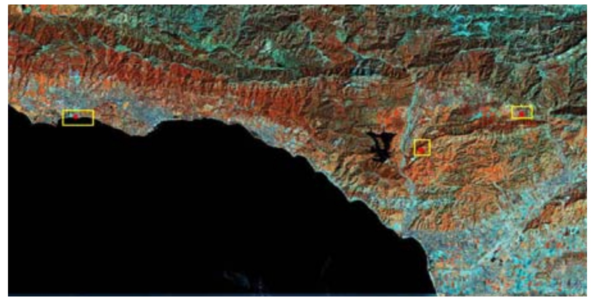


Airborne hyperspectral imagery is used to map different materials at the surface of the earth based on their spectral characteristics. Hyperspectral sensors measure the intensity of solar energy reflected from materials over hundreds of different wavelengths. They can record visible light (comprised of relatively short wavelengths - blue, green and red) as well as longer, near-infrared and short wave-infrared light (VNIR-SWIR sensors). This large number of spectral bands is the basis of the name "hyperspectral" which differs from multispectral sensors having a handful of spectral bands. Hyperspectral sensors are unique in that they have sufficient spectral resolution to identify different surface materials based solely on spectral signatures.

A COOPERATIVE R&D EFFORT

A cooperative hyperspectral group shoot was initiated by The Geosat Committee (VISIT THEIR AAPG EXHIBIT BOOTH #8036) in 1998. The airborne hyperspectral imagery was acquired by Earth Search Sciences, Inc. (ESSI) using their Probe-1 sensor (VNIR-SWIR). The MapFactory discovered evidence in the airborne data that unique hyperspectral signatures could be associated with oil seeps mapped by Thomas Dibblee in Southern California. However, there was no field verification of the findings.

A second cooperative R&D study was initiated by The MapFactory and The Geosat Committee, Inc. (Geosat) in early 2000 to enable The MapFactory to send field crews to the areas discovered in 1998 with a portable spectrometer, detailed mapping program, and GPS receiver.. This study was designed to measure with ground and airborne hyperspectral technology different materials associated with onshore oil seeps and oil-impacted soils in Southern California. The primary objectives of the study were to develop an understanding of the spectral characteristics of oil-impacted soils and seeps and to build a spectral library that would make the detection process more rapid and reliable. Chevron, Royal Dutch Shell, and ExxonMobil sponsored the study and provided key feedback and guidance to the research effort.

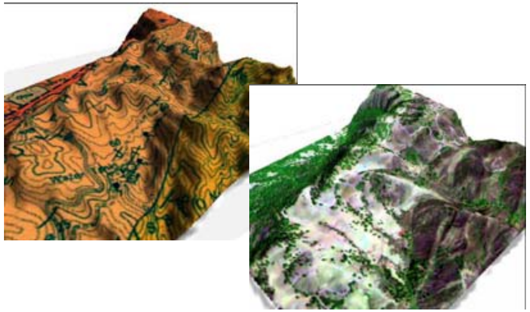


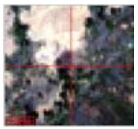
Oil seep deposit at More Mesa located with high accuracy GPS measurements

DETECTING ONSHORE OIL SEEPS WITH HYPERSPECTRAL IMAGERY

James Ellis, Ellis GeoSpatial (as of 2002)

FINDING AN OIL SEEP

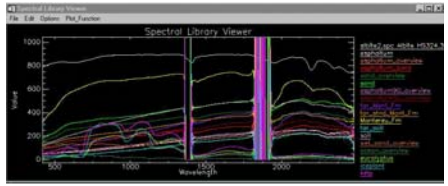




The 2000 study focused on portable field spectrometer measurements at three sites – Sulphur Mountain, More Mesa, and Osborne. In addition, the Probe-1 airborne data cubes were reevaluated using the new field observations and measurements. The field sites were determined by Pat Caldwell based on field experience, State of California Mines and Geology publications (especially Hodgson's 1987 contribution) and the Dibblee Geological Foundation (http://dibblee.geol.ucsb.edu/). These ground photos are from the primary Dibblee oil seep.

BUILDING A SPECTRAL LIBRARY

In order to correlate spectral signatures with specific materials, scientists obtain "pure" samples of the material and collect highly accurate, reflected light measurements in the lab or in the field using a portable spectrometer. The measurements allow spectral libraries to be built that contain various hyperspectral signatures that have been positively identified with specific materials at the earth's surface. Spectral libraries have been constructed for numerous minerals, plants, and manmade materials. This may be the first onshore oil seep library.



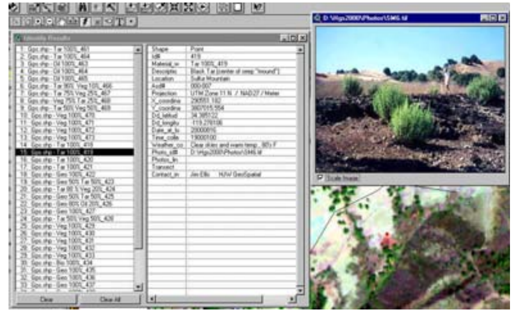
Field spectrometer measurements for different materials

C#	MATERIAL_WITH %	DESCRIPTION	ASD#	X_COORDINA	Y_COORDINA
401	Tar 100%_401	Large semi-smooth knob of seep above or at extent of	000-006	241693.905	3811728.597
402	Tar 50% Geo 50%_402	Overview of Tar/soil mix	040-045	241693.905	3811728.597
403	Tar 50% Geo 50%_403	Mixed pixels of Tar and dry sand	046-050	241693.905	3811728.597
404	Geo 100%_404	Overview of sand	051-054	241693.905	3811728.597
405	Geo 100%_405	Dry sand on beach adjacent to seep	076-080	241693.905	3811728.597
406	Tar 90% Geo 10%_406	Overview of tar/rock (90/10)	018-021	241693.905	3811728.597
407	Tar 50% Geo 50%_407	Overview of tar and rock mix (50/50)	022-025	241693.905	3811728.597
408	Tar 50% Geo 50%_408	Soil and weathered Monterey Formation with Tar	007-011	241693.905	3811728.597
409	Geo90% Tar 10%_409	Tar stained or discolored Monterey Formation	012-017	241693.905	3811728.597
410	Geo 100%_410	Exposed Monterey Formation at sea cliff (west of seep	081-085	241693.905	3811728.597
411	Tar 50% Geo 50%_411	Stratified layers of Tar and soil	026-028	241693.905	3811728.597
412	Geo 100%_412	Soil/sand on terrace adjacent to seep	059_061	241693.905	3811728.597
413	Geo 100%_413	Wet sand	062-064	241693.905	3811728.597
414	Geo 100%_414	Overview of ocean, beyond surf	037-039	241693.905	3811728.597
415	Veg 100%_415	Eucalyptus tree (adjacent to seep)	065-067	241693.905	3811728.597
416	Veg 100%_416	Iceplant	056-058	241693.905	3811728.597
417	Veg 100%_417	Kelp	073-075	241693.905	3811728.597

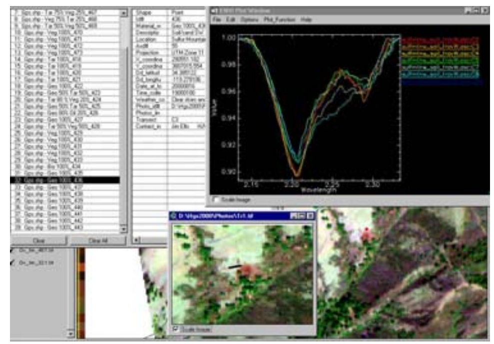
Example of spectral library sites with differing mixtures

Hyperspectral GIS with field site attributes, hot links to ground photos, and Dibblee map showing seeps.

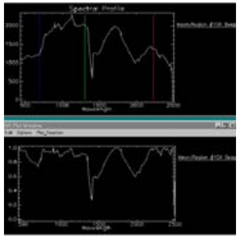
CHARACTERIZING AN OIL SEEP

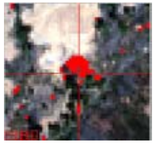


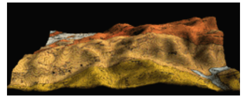
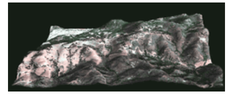
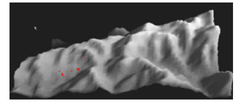
The spectral signatures of both the ground and airborne data for similar materials were consistent. The sensor successfully detected the signal from surfaces impacted by oil. HJW's research indicates that the full spectrum from visible through short wave-infrared light (VNIR-SWIR) needs to be carefully analyzed to differentiate oil-impacted pixels from those that are not impacted. New work processes were developed by HJW analysts with ENVI image processing software to successfully extract this subtle signal from the data cube. To better understand sites, they "unmixed" the signatures of materials occurring within a pixel, allowing the identification of individual materials as well as providing information on their relative abundance.



EXPLORING WITH THE SPECTRAL LIBRARY

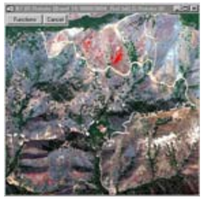
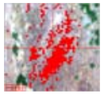
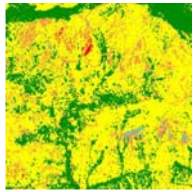




The spectral signature obtained at the primary Dibblee seep was extrapolated across the surrounding terrain to determine if other seeps seen in the field could be detected. This conservative extrapolation successfully detected numerous small oil seeps/oil-impacted soil (red) away from the main seep. A 3D perspective view of the area shows how seep distribution can be related to structural geology and stratigraphy.



An area about 15 km east of the primary Dibblee seep was also analyzed. This extrapolation clearly shows the technique maps significant oil seep/oil staining in several areas. Field verification of the interpretation is recommended. The location of these impacted sites should be integrated with surface and subsurface structure and stratigraphy, historic and current oil field maps, and topography to better understand the exploration significance of these features.

OTHER INDUSTRY APPLICATIONS

A

B


A. A facility within the airborne flight strip seen as (left) natural color image and (right) classified for oil-impacted surfaces (red) using preliminary spectral library being constructed in this study. The classification has not been field-checked. The terrain around this facility has natural oil seeps.
B. A wharf where an oil spill was documented in 1992. Hyperspectral imaging detects oil-impacted surfaces (red) along the edge of the wharf. The right-most image is a classification showing wetlands and onshore roads.

SUMMARY

This cooperative R&D effort provides fundamental support for deploying hyperspectral imaging to detect onshore oil seeps. The oil-focused spectral library, combined with appropriate work processes, skill, and experience, will enable earth scientists to begin considering VNIR-SWIR imaging as another tool for improving onshore exploration. This study demonstrates that hyperspectral technology would be an effective tool to better understand the probability of oil seeps across remote geologic structures.

ACKNOWLEDGEMENTS

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Recent articles in Earth Observation Magazine, Point of Beginning, Geologic Remote Sensing Conference Proceedings, Oil & Gas Journal. and Airborne Remote Sensing Conference Proceedings (2000 – 2002)

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