QUATERNARY MAPPING IN GLACIATED AND VEGETATED AREAS USING SAR AND MULTISPECTRAL IMAGES

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ABSTRACT

Accurate Quaternary geological maps are fundamental in a large number of geoscientific studies, mineral exploration programs and construction engineering projects. In glaciated and vegetated environments, extensive field observations are required to provide information on surficial deposits. Air photos are still the primary logistical tool used to plot field geological information, and to interpret the surface textures of Quaternary units. The use of other remote sensing techniques in providing geological information is increasing. This paper provides examples of the use of SAR and TM images in providing Quaternary and terrain information.

In the Canadian Shield, the thin discontinuous drift-cover and associated vegetation diversity have produced spectral differences on Thematic Mapper data that have assisted in lithologic mapping. The airborne SAR and multispectral images have aided in the delineation of Quaternary units and provided additional insights into the glacial history of the area. In this paper geobotanical terrain indicators have been used to assist the surficial mapping in drift covered areas.

1. INTRODUCTION

In Canada, Quaternary geological maps are published by the national and provincial geological surveys. These maps provide information on construction material, surficial deposits, glacial history and stratigraphy. They are used quite extensively in engineering site investigations (route planning, landfill site location, gravel searches, etc.), in drift prospecting programs, and in hydrogeological surveys.

Aerial photography is used in the initial stages of Quaternary mapping as a means of delineating landforms and surficial materials. In the boreal forest region of Ontario, for instance, engineering terrain maps are produced at a scale of 1:100,000, mainly from airphoto interpretation and subsequent field programs (Gartner, 1980). Aerial photography was first used as an aid in delineating surficial materials and its use was reported by (Tomlinson and Brown 1962, Zsilinszky 1968, Gimbarzevsky 1972, and Mollard and Janes 1984). In these studies, both large and small scale photography (1:15,000-1:120,000) photography was used to delineate the plant communities and landforms associated with surficial materials. Today, the use of aerial photography as an aid in delineating surficial materials is quite routine, and are used quite extensively. The established principles of photo-interpretation for the identification of tree species, glacial landform, soil moisture and surficial materials within the boreal forests were used to interpret the satellite multispectral data for delineating surficial materials.

LANDSAT MSS imagery were used as an aid in delineating surficial materials within the boreal forest region (Singhroy and Bruce 1979, Singhroy and Dixon 1980, Bélanger 1983 and Bélanger and Rencz 1984). These early works have shown that glacial, alluvial and organic deposits can be separated from enhanced LANDSAT MSS data for 1:250,000 scale mapping programs. Satellite images and aerial photography have been used in limited ways to provide information on regional ice flow direction, small-scale terrain typing and the regional distribution of surficial materials based on geobotanical, associations. (Singhroy and Bruce, 1979; Bélanger and Rentz, 1984; Hornsby and Bruce, 1986; and Singhroy et al., 1985). Table I provides a summary of published studies to date on geobotanical remote sensing techniques in support of Quaternary mapping in Canada.

To date, the use of SAR (synthetic aperture radar) images in Quaternary mapping in the forested regions of Canada is limited. However, with availability of ERS-1 and later JERS and RADARSAT the situation will improve. SEASAT and SIR-B images have been used primarily in lineament studies in the Canadian Shield and other glaciated areas (Lowman et al., 1987; Harris, 1991). As these small-scale radar images provide little information on surficial materials, their use was limited. In combination with airphotos, however, the radar imagery was used in small-scale terrain typing for route planning (Singhroy, 1988). In addition, recent studies have shown that different terrain types produce distinctive radar image textures which can be correlated with major lithologic and surficial material units (Singhroy and Barnett, 1988; Ford and Sabins, 1986; Daily et al., 1979). The purpose of the study is to provide some initial results of larger-scale airborne radar for Quaternary mapping programs in glaciated and forested terrains typical of those found over much of Canada, and discuss the uses of TM and integrated SAR/TM data for Quaternary mapping.

2. METHODS

This experiment is part of a larger radar data development program where airborne SAR data in C-band with HH (horizontal-transmit, horizontal-receive) polarization was recorded for the RADARSAT Project Office of the Canada Centre for Remote Sensing over several types of glaciated terrains. Image evaluation was carried out for two areas, each of which had a different type of surficial materials and terrain/landform combination. The sites were located near the northern rim of the Sudbury Basin in northern Ontario, and in The Pas region in northern Manitoba. The mission was flown at an altitude of 20,000 feet, as to produce a spatial resolution of 6 metres by 6 metres. The radar sensor was set for narrow-swath coverage, i.e., for a swath approximately 18 km wide and depression angles from 14 to 45 degrees. Supervised classification and principal component enhancement techniques were performed on a summer TM scene for both sites. Also, the SAR image was geometrically registered to a 1:50,000 topographic data base, then a 5 x 5 direction filter was used to reduce speckle. Such preprocessing is a requirement for the creation of the SAR/TM composites.

3. INTERPRETATION OF RADAR AND TM IMAGES

Sudbury Site

The Sudbury site was chosen because it offered a large variety of Quaternary sediment types within a rocky terrain typical of vast areas of the Canadian Shield (Burwasser, 1979). As a large part of the area is tree-covered, the important link between the materials-vegetation combination and the radar backscatter could be examined. On the radar image of the Sudbury test site, bedrock structure and Quaternary landforms are well defined. An ice-marginal delta formed along the end moraine and extending into a high-level glacial lake in Sudbury Basin, is readily identifiable on the image. Also visible on the image are eskers feeding the delta and downscutting into the delta top and terraces along the end moraine formed during lower lake stages in the Sudbury Basin, Variations in the thickness of glacial sediment cover are also evident of this image. Rock-dominated terrain with very thin, discontinuous drift cover is found along the northern boundary of the image area. The drift cover thickens southward and becomes more continuous immediately north of the end moraine. Rock outcrops on ridges indicate some of the structures and layering of the bedrock within the Sudbury Basin.

Integration of the SAR and TM data (1st PC, TM band 4 and C-HH SAR) have provided information on the influence of topography (provided by the SAR data) as vegetation distribution. This combination together with the comparison of the enhanced TM and C-SAR image have provided a useful visual product for interpreting surficial unit boundaries. The enhancement is particularly effective where there are links among landform vegetation and surficial materials.

The Pas Site

According to the Quaternary geology map of the area produced by Singhroy and Werstler (1980), the study site is part of the fluted Pas moraine. The surficial deposits consist of clay till, sandy-stony ablation till, and beach sand and gravel. The lower areas of the moraine contain organic deposits.

Both the supervised classification and the principal component enhanced techniques produced image vegetation maps which correspond quite well to the Quaternary units. Alluvial, organic beach sand and gravel, and ablation till areas were easily separated because of their distinct vegetation cover. However, there were some confusion between areas covered by clay till and shallow organic deposits. This is because the black spruce forest grows on both sites which are wet. Despite these minor differences the image maps were useful for field mapping and sampling tools.

The radar data for the site was geometrically registered to the topographic data base, then a 5x5 directional filter was used to reduce speckle. Comparing the filtered radar image with the surficial geology map for the area revealed little correlation in terms of Quaternary features and materials, partly as a result of low relief. When the image was superimposed on the TM band 3 and 5 composite, additional information on the surficial geology became evident. Areas of ablation till, clay till, beach deposits, and organic terrain were delineated on the basis of associations between vegetation and surficial materials.

4. CONCLUSIONS

Although further work is ongoing on seasonality and viewing geometry, some conclusions can be drawn regarding the use of radar images and TM data for Quaternary geology mapping in forested glaciated regions:

1. Radar imagery provides valuable information on landform and terrain roughness. As landforms provide important clues to surficial materials, radar images are a useful and practical tool for Quaternary mapping.

2. In areas where there are relationships between surficial sediments and vegetation and landforms, the radar/TM colour composite provides a useful technique for delineating Quaternary units, particularly if the unit boundaries are controlled by landforms.

It is hoped these early results will encourage further development of integrated SAR, TM or SPOT products to facilitate surficial mapping in vegetated covered terrains.

NOTE: Colour images products will be shown during the verbal presentation of this paper.

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TABLE I: SURFICIAL DEPOSITS MAPPING FROM GEOBOTANICAL REMOTE SENSING IN GLACIATED TERRAINS: SUMMARY OF RESULTS FROM THE BOREAL FOREST REGION

SURFICIAL DEPOSITS	LANDFORM/ MOISTURE	PLANT COMMUNITIES	SENSORS	INTERPRETATION TECHNIQUES	LOCATION	REFERENCES
Rock debris	ground moraine (bouldery)	Black Spruce, Jack Pine and White Birch	Black & white photography scale 1:15,000	Photo Interpretation	Northern Ontario	Tomlinson & Brown (1962) Zsilinszky (1968)
Sand and coarse material	sand plain & glacial outwash	Dense stands of Jack Pine				
Medium materials						
Clay till	Clay till plain (well drained)	Black Spruce, White Birch/Popular Mix				
Fine materials Silt & clay	Glaciolacustrine plain & alluvial plain	White Spruce/Aspen and Alder				
Organic Deposits	Bogs	Black Spruce & Larch				
Sandy to silty tills	till plain (imperfectly drained)	Mainly Black Spruce	Infrared Photography 1:120,000	Photo Interpretation	North Western Alberta	Mollard & James (1984)
	till plain (well drained)	White Spruce, Aspen (upper slope), Black Spruce (lower slope)				
Medium to coarse textured materials	glacial drift (well drained)	Pure Pine Sands	Black & white Photography 1:80,000	Photo Interpretation	Smokey River Valley	Gimbarzevsky (1972)
coarse grained materials	glacial drift (poor drainage)	Black Spruce				
sand	sand dunes (dry)	Aspen-pine-spruce				
Several till types	Ground moraine (well drained)	Deciduous forest	LANDSAT MSS	Classification (1) techniques (2) principal components (3) field spectra	Thetford Mines Region STAR and Wollaston Lakes	Bélanger & Rencz (1984) Bélanger (1991)
Glacial till	Ground moraine (well drained)	Mixed coniferous and deciduous forest	LANDSAT MSS 1:250,000	Unsupervised classification techniques	Chalk River, Ontario	Bélanger (1983)
Thin till	Ground moraine (well drained)	Jack Pine	LANDSAT TM Scale 1:100,000	Unsupervised classification	Sudbury	Hornsby & Bruce (1986)
Glaciofluvial sands	Outwash (well drained)	Poplar/Birch				
Thick till	Ground moraine (moderately drained)	Birch/Poplar				
Clay	Glaciolacustrine	Silver Maple				
Clay till	Moraine plain & terminal moraine (moist to wet)	Black Spruce, Jack Pine, Aspen, Willow	LANDSAT MSS 1:250,000	Unsupervised classification	The PAS, Manitoba	Singhroy and Bruce (1977)
Sand silt and clay	Alluvial flood Plain (wet)	Willow, Alder and sedges				
Organic deposits	Bog & Fen (wet)	Black Spruce & sedges				
Thin sandy till	Ground moraine (well drained)	Coniferous forest	TM 1:100,000	Enhanced colour 457 composite	N.W. Ontario	Singhroy, Ellis and Janes (1985)

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Glaciolacustrine silt & clay	Lake plain (moist)	Deciduous forest				
Thick clay till	Ground and terminal moraine (moist to wet)	Mainly Black Spruce	TM 1:100,000	Supervised classification	The PAS, Manitoba	Singhroy et al. (1992)
Thin stoney clay till & beach deposits	Ground moraine and littoral deposits (well drained)	Mixed forest: 60% Deciduous 40% Conifers	C Band Radar	Principal component data comparison method		
Organic deposits	Bogs and fens (wet)	Stunted Black Spruce and sedges		Stretched composite		
				Radar TM composite		
Thin stoney till	Ground moraine	Mixed deciduous and conifers	Airborne C-SAR wide swath 1:50,000	Visual Interpretation	Newfoundland	Graham and Grant (1991)
Thin sandy/stony till	Ground moraine	Mixed deciduous and conifers	Airborne C-SAR 1:20,000	Visual Interpretation	Northern Manitoba	
	Ice marginal delta, Esker	Mainly deciduous	Airborne C-SAR 1:20,000	Visual Interpretation		Singhroy et al. (1992)
Thick sandy till	Fluted till plain	Mixed forest, deciduous and conifers	Airborne C-SAR 1:20,000	Enhanced C-SAR with 5x5 directional	Northern Ontario	