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PRELIMINARY RESULTS OF POLARIZATION SIGNATURES FOR GLACIAL MORAINES IN THE MONO BASIN, EASTERN SIERRA NEVADA.

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1. INTRODUCTION

The valleys of the Mono Basin contain several sets of lateral and terminal moraines representing multiple stages of glaciation. The semi-arid climate with slow weathering rates has preserved sequences of nested younger moraines within older ones. There is a well established relative chronology (Sharp and Birman 1963, Burke and Birkeland 1979, Gillespie 1982) and recently exposure dating has provide a new set of numerical dates (Phillips et al. 1990). The moraines span the late Wisconsin (11-25 ka) to the Illinoian (130-190 ka) glaciations. We are using the Mono Basin area as a "calibration site" to establish remote dating techniques for eventual transfer to the more inaccessible but geomorphically and climatically similar moraines of the South American Andes Mountains. Planned polarimetric SAR imagery acquired by JPL AIRSAR (South American Campaign) and SIR-C (Andes super-site) will be analyzed to establish chronologies of previously undated moraine sequences in a study of Pleistocene climatic change in the Southern Hemisphere.

The dry climate and sparse vegetation is also favorable for correlation of ground surface roughness with radar polarization signature. The slow weathering processes acting over thousands of years reduce the size, frequency and angularity of surface boulders while increasing soil development on the moraines. Field observations based on this hypothesis (Sharp and Birman 1963) result in relative ages consistent with those inferred from nested position within the valley. Younger moraines, therefore, will appear rougher than the older smoother moraines at scales measurable at AIRSAR wavelengths. Previously documented effects of ground surface roughness on polarization signatures (Evans et al. 1988, Ray et al. 1991) suggest that analysis of moraine polarization signatures can be useful for relative dating. The technique may be extended to predict numerical ages.

The data set reported here were acquired on September 8, 1989 with the JPL AIRSAR collecting polarimetric imagery at C- (5.6 cm), L-(24 cm) and P-band(68 cm) with a flight-line parallel to the strike of the mountains. Phase calibration was performed on the analyzed scene by setting the co-phase of a smooth lake to zero as described in Zebker and Lou (1990). Absolute amplitude calibration was not possible because corner reflectors were not deployed.

2. ANALYSIS

The Walker Valley moraine complex (Bloody and Saw Mill Canyon) was chosen for initial analysis because it contains moraines from five distinguishable glacial episodes (Table 1). Estimates of the surface roughness of the crests of the moraines were determined from 1-D Fourier transforms of a series of 15 m linear push-rod profiles (10 cm horizontal spacing, 1.0 mm vertical resolution) from the moraine crests (Fox 1989). This measure of surface roughness was found to correlate with the relative moraine ages

(Table 1). The crests were measured because they were the areas of minimum soil development and least vegetation, enhancing boulder exposure, and thus provide the optimal discrimination based on ground surface roughness. Efforts were made to avoid vegetation during profiling. Fox found that surface roughness correlated best with the image pixel DN values for P-band HH when compared to linear polarizations of the three bands (Fox 1991). The following preliminary analysis will focus on P and L-band polarization signatures because of their sensitivity to the large scale roughness presented by individual boulders.

Moraine (Glaciation)	Age [ka] (best estimate)	Surface Roughness
Tioga	14 a	6.70
Tenya	40 a	6.51
Tahoe Younger	60-85 b	6.37
Tahoe Older	<118 c	6.22
Mono Basin	130 a	5.12

Table 1. Walker Valley moraine classification with estimated age and measured ground surface roughness. a- (Crook and Gillespie 1986) b- (Bursik 1989) c- (Gillespie 1982)

Polarization signatures were created for each moraine from pixels along and adjacent to their crests'. The initial results are based on calculations from typical signatures of each moraine. Further research will include more samples for a statistically sound study.

The scattering from an object will become more diffuse as the roughness of the target increases relative to the illuminating wavelength. Polarization signatures reflect the degree of diffuse scattering in their measure of co- and cross-polarized radar cross section as a function of all possible transmit polarizations. The most common way of estimating the diffuse component is with the pedestal height (vanZyl et al. 1987) calculated as the ratio of the co-polarized minimum to the signature maximum. An alternative approach which uses only circular polarization for estimation of diffusivity is the circular polarization ratio (referred to here after as CPR) as defined by Ray et al. (1991). The right-hand circular polarization ratio is calculated by dividing the cross-polarization right-hand response (transmit RH receive LH, expected for a smooth object) by the co-polarizied right-hand response (transmit RH receive RH expected from a diffuse object), thus comparing the directly reflected power to the diffusely scattered power. Rough objects would theoretically have lower CPR's than smooth objects (relative to wavelength).

Pedestal heights and right-hand CPR (direct/diffuse) values for the five moraines at P- and L-bands are shown in Table 2. The P-band data show consistent trends for decreasing roughness with successive glaciations. The pedestal height decreases and the right-hand CPR increases. The L-band data show the same trends except for the Mono Basin moraine, it does not appear to be the smoothest (oldest) using either the pedestal or the CPR technique.

Moraine	Pedestal Height		R-H Circular Polarization Ratio	
(Glaciation)	L	P	L	P
Tioga	.1280	.1633	.4621	.1243
Tenya	.1230	.1587	.5776	.2143
Tahoe Younger	.0888	.0904	.6549	.4429
Tahoe Older	.0714	.0702	1.000	.6143
Mono Basin	.1178	.06442	.7698	1.000

Table 2. Walker Valley moraine classification with L- and P-band pedestal heights and right-hand circular polarization ratios (normalized)

3. SUMMARY

The preliminary results indicate that the polarization signatures from the glacial moraines of the Walker Valley may be used as a relative dating tool. Specifically, the parameters of pedestal height and the ratio of circular expected to circular diffuse polarization have shown correlation with moraine age at P-band and to a lesser degree at L-band. The established correlation of relative moraine age with crest ground surface roughness provides the physical link from scattering mechanism to relative age. The violation of the trends at L-band for the Mono Basin moraine may be the result of diffuse scattering from vegetation creating the "appearance" of a rougher surface. The Mono Basin moraines have the most densely vegetated crests. The ground shrubs may have less of a response at the longer P-band wavelength. This hypothesis may be further supported if the Mono Basin moraine appears even rougher at C-band.

Additional signatures need to be acquired at more locations representing a diverse set of incidence angles, local incidence angles, pixel numbers used for signature, and crest orientations to confirm the observed trends. The shape of the polarization signatures will be further analyzed for implications of the nature of the scattering mechanism. A more detailed and comprehensive characterization of the moraine surface roughness is planned through a high resolution DEM to be generated from low altitude stereo photogrammetry. The potential exists for relative dating of moraines in inaccessible areas from remote polarimertic SAR platforms.

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