EVALUATION OF AIS-2 (1986) DATA OVER HYDROTHERMALLY ALTERED GRANITOID ROCKS OF THE SINGATSE RANGE (YERINGTON) NEVADA AND COMPARISON WITH 1985 AIS-1 DATA.

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ABSTRACT

The 1986 AIS-2 flights on 29 September 1986 along two subparallel lines (bearing 013°) over the western flanks of the Singatse Range, were designed to traverse three major rock assemblages--the Triassic sedimentary sequence; the granitoid rocks of the Yerington batholith (Ann Mason and MacArthur) and the Tertiary ignimbritic ash-flow and ash-fall tuffs. Both Ann Mason and MacArthur sites are hydrothermally altered to a quartz-sericite-tourmaline mineralogy (Dilles, 1983; Proffett and Dilles, 1984; Einaudi, 1977).

The original AIS-2 data set showed numerous line-dropouts and a considerable number of randomly distributed, dark pixels. A second decommutation of the master tape (at NASA/ARC) produced a much better product, reducing the dropout essentially to near zero and the dark pixels by about 75%. These were further removed by a spatially-active 3 x 3 filter, which replaced a "bad" pixel by the average of its eight neighbors, if that pixel deviated from this local average by 30 DN.

Vertical striping was removed by histogram-matching, column by column. Finally, a "log-residual" spectrum was calculated which showed the departure of a 2 x 2 pixel area from the spatially- and spectrally-averaged scene.

A 1:1 correlation was found with the log-residual AIS-2 data and a large open pit area of gypsum. An area with known sericite agreed with the overflight data, and an area known to be free of any significant amount of O-H-bearing minerals showed no evidence of any in the AIS-2 log-residuals.

INTRODUCTION

AIS-2 imagery was obtained along four almost N-S lines (bearing 013°) over the western flank of the Singatse Range, near Yerington, approximately 120 miles SE of Reno, Nevada. Concurrent 35 mm Nikon B/W photography was taken to aid in ground location, with airborne video as an adjunct.

The four 1986 flight lines (flight 86-009-09, 29 September 1986) were flown between 9,000 ft. and 12,000 ft. above ground level (2.74 Km to 3.66 Km). The 013° bearing for the 15 Km lines was chosen to traverse the strike length of the Triassic limestone sequences (Ludwig area) at the south end; the Jurassic granitoid rocks of the Yerington batholith (Ann Mason area); and the Singatse Peak Tertiary ignimbritic tuffs. At the

northern end (in the MacArthur area) a repeated section of the granitoid rocks was also traversed. A total of 14 "parent" rock types was sampled - 5 Triassic sediments, 3 granitoid types, and 6 members of the ignimbritic sequence. In addition, two sequences of "hydrothermally-altered" granitoids were overflown.

This paper deals initially with the processing of the 1986 data and then covers some of the geological results relating the airborne data to ground-measured VIRIS spectra taken from underneath the flight lines.

DATA QUALITY

The 1986 AIS-2 data sets as supplied initially contained severe line-dropouts and extensive ("pepper and salt") randomly-placed (usually dark) anomalous single pixels. All attempts to remove these pixels proved fruitless. We requested and received from NASA/ARC, a second attempt at decommutating the master tape which was of decidely better quality (see Fig. 1).

The imagery was still badly striped (vertically) and software had to be developed (Table 1) to take care of these artifacts.

Table 1

SOFTWARE PROGRAMS - STANFORD

INPUT:	AIS32	Reads AIS-1 and AIS-2 tapes, displays image data, writes 80-line disk file (of channels 1-128; 76-117; or 97-128).
PROCESSING:	DEST32	Removes the vertical striping from an AIS image, forcing histogram for each vertical line to be equal.
	DESPIKE	Removes isolated bad pixels from an AIS image. Works in the spatial domain. Compares pixel to its 8 neighbors, replaces by average if outside tolerance (generally 30 DN).
	DESTAP	Destripes a whole flight-line; writes output to a second tape.
	ANDY32	Applies "log-residual" correction to an AIS image file.
	ANDYTAP	Same as ANDY32, but builds its averages from readings from the flight-line data from tape.
DISPLAY:	MULTI32	Displays as many channels as possible of an AIS file, in monochrome.
	TVAIS32	Displays a color-composite image of 3 AIS channels, and graphs the spectra of selected pixels.

DATA PROCESSING

Data Omission

This year we elected only to process the 2.2 micron region of the data (compare with Lyon, 1986), and further to concentrate only on those channels (#76-117) with a high radiance level.

We also deleted the last 11 channels (#118-128) to avoid possible "second-order" grating effects (noted in AIS Workshop II Report, p. 7, footnote C). The remaining 42 channels proved to be very useful in data analysis and less noisy than those we had omitted.

Image Extraction and Viewing

With the advent of the 64-pixel swath of AIS-2, we had to change the dimension statement of our software (Table 1). In addition, because of the size of our display screen (640 x 480 pixels) and with our desire initially to view as many channels of the 42 as possible, we again selected for display, 32 windows of 80 flight-line segments.

MULTI32 (Table 1) can be used to display any 32 continuous channels at once for these 80 flight-line segments, using either raw, destriped, despiked, or log-residual image data.

TVAIS32 will use any three channels (those selected from the MULTI32 display with maximum spectral contrast) and display them (2X enlarged) side by side, with their color-composite image on their left (Fig. 2A). A second aspect of TVAIS32 is the graphical mode. The 3-band color image is retained, and the three individual monochrome images are suppressed, being replaced by a spectrum (of 42 channel-elements) drawn horizontally across the screen, tied to the specific 2 x 2 pixel area from which their average graph was taken. This graphical display can be keyed to ground localities from which sample-spectra have been taken (Figs. 2B,D), or overlain onto geological maps, etc.

Our strategy for field correlation using the AIS imagery is based on the need to locate on the ground these specific pixels whose graphs show significant mineral information. While the 80 lines by 64 pixel segments may seem small, they cover 1.6 x 1.3 Km at a 20 m pixel size.

Image Restriping

Severe vertical striping was obvious in the raw imagery. The program DEST32 removed most of this by forcing the histogram of each column of pixels to be equal. Some intermittently (vertical) noisy columns still retained their bad data even after this action (noted especially in channel 97 (see Figs. 1C,D).

Image Despiking

The program DESPIKE operates on a 3 x 3 matrix in the spatial domain, and examines the central pixel DN, by comparing it to that of its eight neighbors. If the center pixel has a DN value differing from the 8-pixel mean, over a "tolerance" of 30 DN, it is replaced by that average, and the kernel moves forward. All 42 channels are so processed. The tolerance, however, cannot be made too small as it would soon give the kernel the effect of a 3 x 3 smoother. As the random spikes have non-zero DN with a

clear distribution in greyness, some "noise" is left in the data, if it is within the 30 DN tolerance.

This problem is markedly enhanced by the "log residual" processing and leads to significant levels of noise in that final product (Figs. 1E,F).

Log-Residual Processing

This algorithm has been borrowed from Dr. A. A. Green, CSIRO, Australia, but we have modified it slightly from its original expression (Green and Craig, 1985). Both these formulations also differ from a later "JPL log-residual" which appears only to use the first two items (A,B), of equation 4. The "offset" term (D) is probably used in all three forms in actual utilization by manipulation of the display system.

Our version of this statistically-based method (Roberts, et.al., 1986, p. 22) uses the relationship

$$DN_{s,\lambda} = T_s R_{s,\lambda} E_\lambda \tag{1}$$

where $DN_{s,\lambda}$ = radiance , or the DN of each channel (λ) for each spatial $pixel_{(s)}$ in the data; T_s = a topographic factor for slope orientation effects; R_s is the desired "reflectance" for each channel at each spatial pixel, and E_λ is a measure of the average irradiance.

$$\underline{\text{"TOPOGRAPHIC" term}} \quad T_s = \frac{1}{128} \sum_1^{128} \log (DN_{s,\lambda}) \tag{2}$$

in the spatial domain

$$\underline{\text{"IRRADIANCE" term}} \quad E = \frac{1}{N} \sum_1^N \log (DN_{s,\lambda}) \tag{3}$$

in the spatial and spectral domain for each λ

Equation (1) in a logarithmic form, can be rearranged as follows:

$$\log(R_{s,\lambda}) = \log(DN_{s,\lambda}) - \text{Avg. } (\log_\lambda) - \text{Avg.}(\log_s) + \text{offset} \tag{4}$$
$$\quad\quad\quad\quad\quad \text{"A"} \quad\quad\quad\quad \text{"B"} \quad\quad\quad \text{"C"} \quad\quad\quad \text{"D"}$$

This also can be thought of as

Output spectrum = raw spectrum - average spectrum - pixel
brightness + image brightness

where all are in logarithmic form (see Fig. 4).

RESULTS

Anhydrite (gypsum)

AIS-2 Run 604 at lines 650-730 crossed over the Ludwig open pit in the Triassic anhydrite (gypsum) beds. The open area of the pit, together

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with the (white) spoil dumps gave a relatively pure, large target for analysis, covering two patches about 15 x 15 pixels each.

Figures 1A-F show the several steps of the processing and analysis. Figures 1A,B are a portion of the RAW data seen in a MULTI32 presentation. Figures 1C,D represent the same data after "cleaning-up" with DEST32 and DESPIKE operations. Figures 1E,F show the result of the ANDY32 log-residual process, now revealing the two dark patches (between the letters A,B,C) in channels 76, 77, and 78 corresponding to the low reflectance of gypsum in those wavelengths (1945, 1956, 1966 um). Figures 2A,B complete the analysis with a graphical presentation of selected 2 x 2 pixel areas emphasizing this lowered reflectance. A second broad low appears centered at channel 100 (2200 um).

Figure 2B should be compared with Figs. 5B and 6B, both showing ground spectra of the pit area taken with the GER VIRIS field grating spectrometer. Only the area of the spectrum from 1945 to 2380 um is used by channels 76-117 of AIS-2. This area is stippled on Fig. 5B and enlarged to cover all of Fig. 6B, so that a direct comparison may be made between the AIS-2 "residual-reflectance" and the ground equivalent. The second broad low appears at 2220 um in the ground spectrum (Fig. 6B).

Limestone

AIS-2 Run 602 lines 100-180 passed directly along the strike length of the Mason Valley limestone, a steeply-dipping formation on the west flank of the vertically-plunging Ludwig anticline. In our field spectral work we have noted that on many limestone outcrops the surfaces do not show "limestone" (calcite) spectra, but these are rather more clay-like. Figures 5F and 6F are examples of this and show O-H absorbance more typical of a mixed-layer illite-chlorite phase. Other spectra show a montmorillonite clay to be the surface composition. This is probably residual clay from dissolution of the limestone, or "mud" from summer thunder storms.

Figure 2C shows the log-residual results using MULTI32 with absorptions (black) at channels 107-112 (2275-2329 um), much shorter than channel 113-114 typical of calcite. This may reflect more of a magnesian-rich carbonate (dolomite), although the ground VIRIS spectra of Fig. 6D show the typical very sharp peak at 2339 um (channel 113) of calcite.

Hydrothermal Alteration

AIS-2 Run 604 at lines 1310-1390 crosses almost at right angles over the thin, WNW-trending zones of hydrothermally-altered quartz monzonite of the Yerington batholith, immediately south of the creek bed along which runs the E-W Mickey Pass road. This area is called Ann Mason. (The same run at its northern end also passes over the MacArthur zone of comparable mineralization).

Figures 3A,B show the log-residual displayed with MULTI32, with a darkened strip (in the lower half of each image) in channels 97-101 (2169-2211 um), with a secondary darkening of channels 109-115 (2300-2360 um). Sericite is a major component of this alteration at this site (Dilles, 1983) and our field VIRIS spectra show a minimum at 2204 (channel 100) and another at 2355 um (channel 114, Fig. 6E). Alunite (Fig. 6A) with a minimum at 2173 (channel 97) would be a better match with the AIS-2 data

(channel 97-101) but is unknown from any ground samples within several miles of this locality.

AIS-2 Run 604 at lines 1225-1305 shows the total absence of any O-H in the log-residuals display (Fig. 3C) using MULTI32. This is in agreement with field observations and is confirmed also by a lack of absorptions in the 2.2 um channel of the NS 001 TMS scanner, flown concurrently with the AIS-2.

CONCLUSIONS

1.   AIS-2 has severe vertical striping but this can be removed by histogram-matching, column by column.

2.   AIS-2 shows random low-valued (but non-zero) pixels, generally located in the darker (lower radiance) areas. Some 1-2% are brighter than average (but are not 255 DN). Most of these can be removed by a 3 x 3 (spatial) mean-matching kernel, with a "replacement" tolerance of 30 DN.

3.   AIS-2 can be directly related to ground-acquired VIRIS spectra, if the "outcrop" shows a significant percentage of ("lag") rock fragments, or has been bulldozed clear of surface debris. Fine dust-silt between (and under) the surface fragments invariably has a VIRIS spectrum of a montmorillonite clay. Some mixed-layer ("illites") show also in this fine material.

4.   Significantly, AIS-2 flight data from over rocks known to show no O-H in surface VIRIS spectra, do not show any AIS-2 minima attributable to O-H. This was not so clear in the 1985 AIS-1 data due to a higher noise component (see Fig. 3D).

5.   Direct confirmation of dolomitic limestone outcrops with calcite/dolomite spectra from the AIS-2 data (Mason Valley limestone) is occasionally possible (Fig. 3A,B).

REFERENCES

Dilles, J.H., 1983, The petrology and geochemistry of the Yerington batholith and the Ann-Mason porphyry copper deposit, western Nevada, Unpublished Ph.D. thesis, Applied Earth Sciences Department, Stanford University, 600 pp.

Einaudi, M.T., 1977, Petrogenesis of the copper-bearing skarn at the Mason Valley mine, Yerington district, Nevada: Econ. Geol. 72, p. 769-795.

Green, A.A., and Craig, M.D., 1985, Analysis of aircraft spectrometer data with logarithmic residuals: Proc. AIS Data Analysis Workshop, April 8-10, 1985, G. Vane & A.F.H. Goetz, eds., Jet Propulsion Lab, Cal. Tech., Pasadena, California, p. 111-119.

Lyon, R.J.P., 1986, Comparison of the 1984 and 1985 AIS data over the Singatse Range (Yerington) Nevada: Proc. Second AIS Data Analysis Workshop, May 6-8, 1986, G. Vane & A.F.H. Goetz, eds., Jet Propulsion Lab, Cal. Tech., Pasadena, California, p. 86-95.

Proffett, J.M., Jr., and Dilles, J.H., 1984, Geological Map of the Yerington district, Map 77, published by the Nevada Bureau of Mines and Geology, University of Nevada, Reno, Nevada. One page map in folder.

Roberts, D.A., Yamaguchi, Y., and R.J.P. Lyon, 1986, Calibration of various techniques for calibration of AIS Data: Proc. Second AIS Data Analysis Workshop, May 6-8, 1986, G. Vane & A.F.H. Goetz, eds., Jet Propulsion Lab, Cal. Tech., Pasadena, California, p. 21-30.
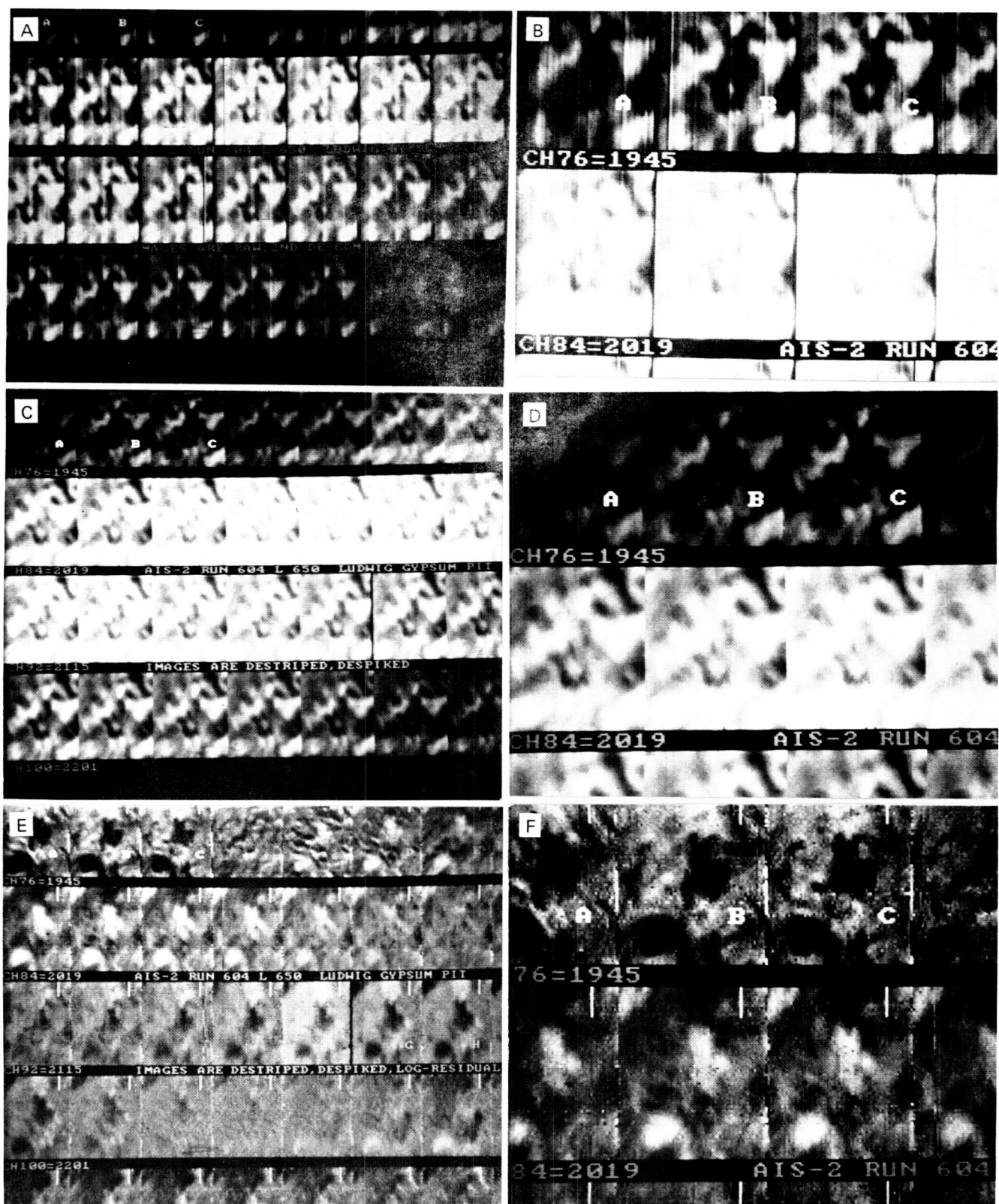
Figure 1. 64 pixel x 80 line flight segments, Run 604 lines 650-730, 29 September 1986. 32 contiguous channels (from #76-117) may be viewed using MULTI32. A. Raw AIS-2 data, 2nd decom.; B. 2X mag.; C. Destriped and despiked; D. 2X mag.; E. Log-residual "reflectance"; and F. 2X mag.

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Figure. 2. Run 604, lines 650-730. TVAIS32 display of 64 x 80 flight segments. A. (left) B/W view of color composite. Three monochromes to right are CH 77,85,111. Selected to show max. spectral contrast. B. Same data (left) B/W view of color composite. Spectra (of 42 channels) keyed to specific pixel sites. Note steep rise (G) at CH 76-79 typical of gypsum. Broad "valley" at 2201 um is also gypsum. C. MULTI32 display, Run 602, lines 100-180, over limestone. Note black areas in CH 106-111 (C) and major absorptions at 2275,2307 (D).
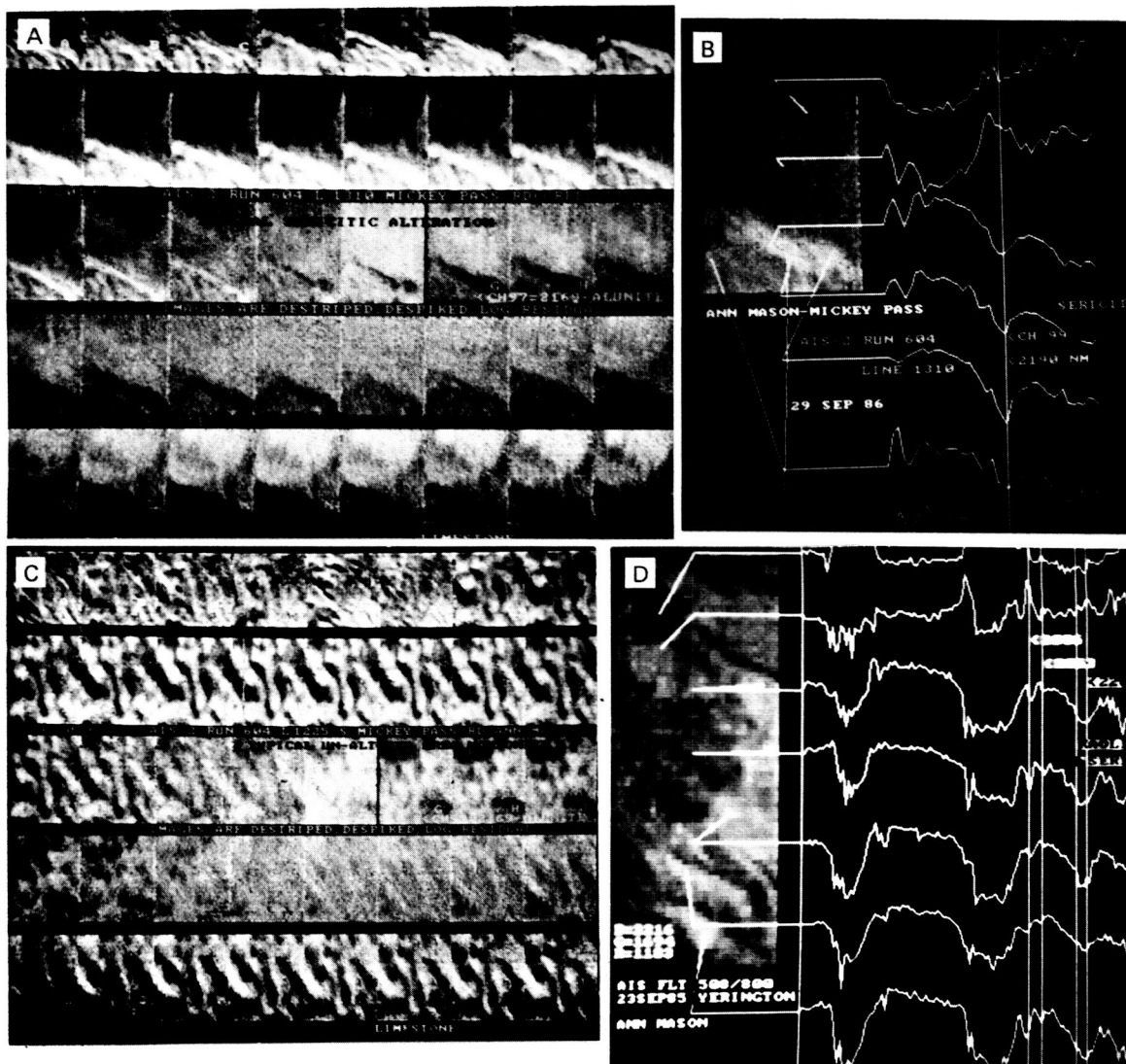
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Figure 3. A. MULTI32 display, Run 604, lines 1310-1390, over area (Ann Mason) of typical sericitic alteration (lower half, oblique strip). Dark channels are 97-102, and 108-115. B. Graphs show CH 99, 2190 um minima. C. Similar display, Run 604, lines 1225-1305, same rock type but <u>without significant sericite alteration</u> on ground examination. D. 1985 AIS-1 graphical display of an area close to A,B above. Note high noise content (128 channels).
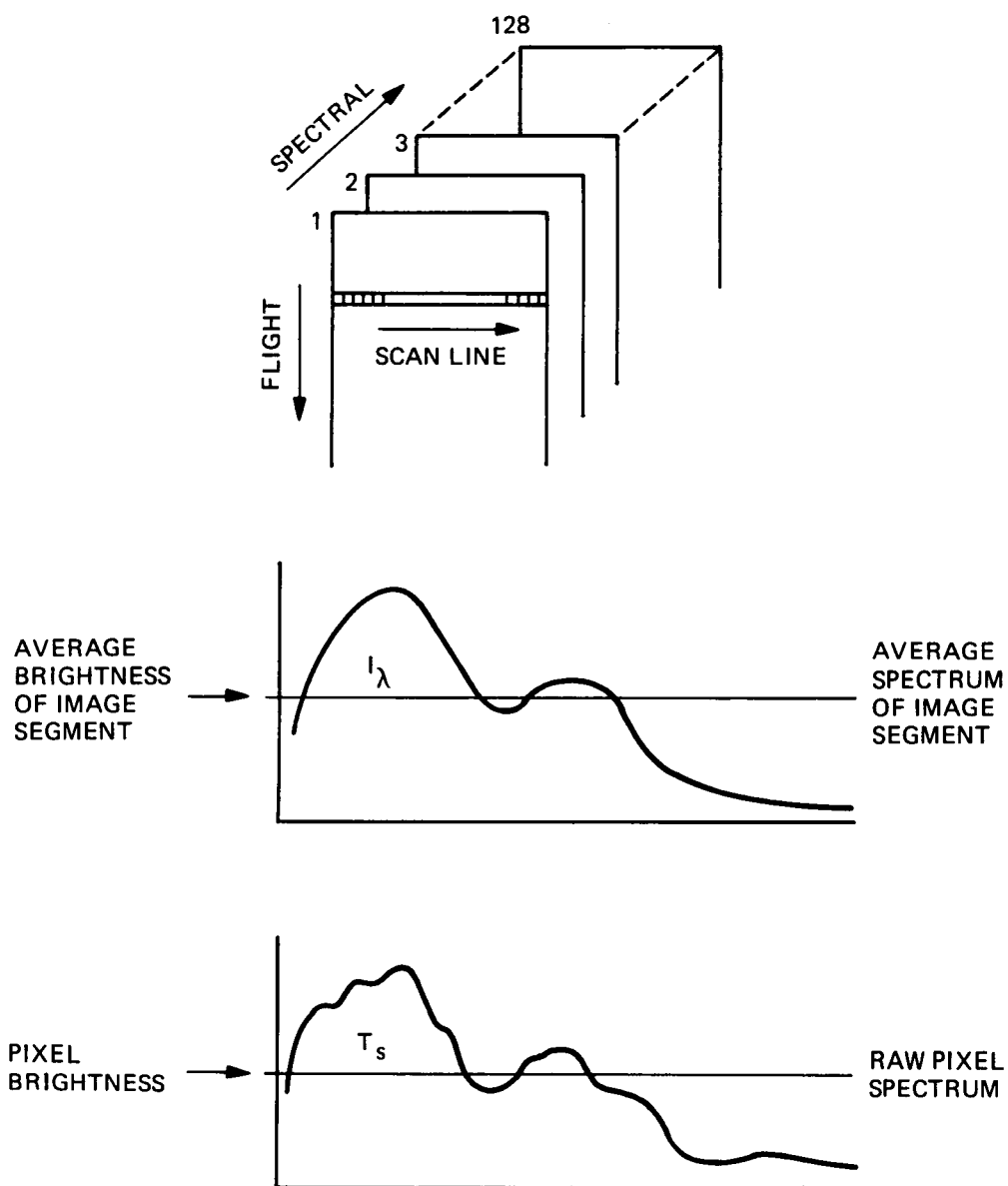
Figure 4. Diagrammatic representation of the log-residual "reflectance" processing.

Figure 5. VIRIS ground spectra, full spectrum 400-2500 um. A. Goldfield, Nevada, alunite; B. Yerington (Ludwig) gypsum; C. Hannapah, Nevada, montmorillonite; D. Ludwig limestone; E. Ann Mason sericite; F. Natural surface of Ludwig limestone - note O-H features.
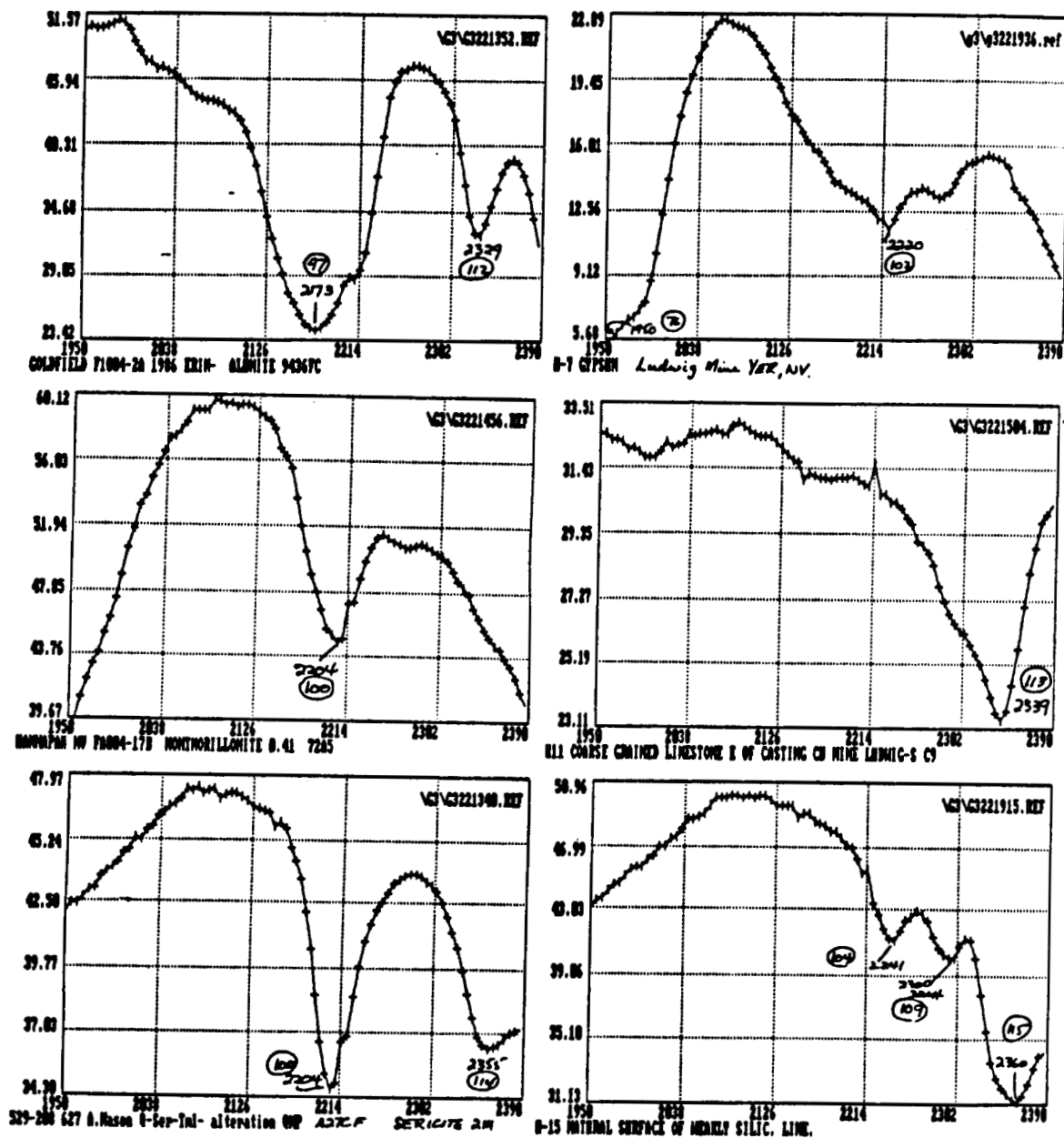
Figure 6. VIRIS ground spectra, portion equivalent to CH 76-117 of AIS-2 (1950-2390 um).   A. Alunite; B. Gypsum; C. Mont-morillonite; D. Fractured surface limestone; E. Sericite; F. Natural surface of limestone.