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Geological Applications of Thermoluminescence Measurements Made with Equipment for Simultaneously Determining Intensity, Wavelength and Temperature*

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ABSTRACT

Thermoluminescent spectra measurements at closely spaced temperatures have been used to study: 1) TL of carbonate rock near lead-zinc deposits, apparently a useful exploration tool, 2) the radiation induced TL of quartz, useful for uranium exploration, and 3) thermally induced modifications of the feldspar albite.

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The equipment for recording thermoluminescence (TL) emission spectra at closely spaced temperature intervals, the "3-D" apparatus [1], has been used for a variety of geoscience studies. Included are the development of methods for locating lead, zinc and fluorite mineralization in carbonate host rock, uranium deposits in sandstone, and the investigation of thermally induced modifications of the feldspar albite.

THERMOLUMINESCENCE OF CARBONATE HOST ROCK CONTAINING LEAD, ZINC AND FLUORITE MINERALIZATION

The natural TL of carbonate rock containing Pb-Zn deposits has been extensively investigated, primarily by McDougall [2]. However, these studies have not resulted in the adoption of TL techniques for Pb-Zn exploration. Consequently, the possibility that TL could be used for Pb-Zn exploration was re-examined using the 3-D apparatus. Two new approaches were tested. First, the radiation induced, not the natural, TL was examined. Second, the emission spectra were examined to determine if host rock in the vicinity of mineralization exhibited emission bands not found in barren rock. Studies were made on carbonate rock containing known Pb, Zn and fluorite deposits, in South West Africa, Mexico and the United States [3,4,5]. Typical measurements are illustrated in Fig. 1. Both dolomite and limestone exhibit only single emission bands, at approximately 2 eV. Dolomite glow curves contain 3, and limestone 4, prominent glow peaks. Emission bands that could be correlated with mineralization have not been observed. After 10^6 R ^{60}Co irradiations, glow peak temperature, emission spectra peak energy, full widths at half maximum, and glow peak intensity all vary with distance-from-ore in a systematic manner. In particular, as shown in Fig. 1, the glow peak intensity is low in the ore, rises to a pronounced maximum, or maxima, close to the ore and then decreases irregularly until it reaches a low level. The extent and height of the pattern depends on ore grade and thickness. The glow peak intensity vs distance-from-ore pattern would appear to be the basis for a very useful exploration tool.

THERMOLUMINESCENCE OF SANDSTONES CONTAINING URANIUM DEPOSITS

The artificial TL of natural "vug" quartz has been studied with the 3-D apparatus, as part of an effort to develop a TL uranium exploration technique [6]. In all crystals studied the emission is confined to a single band near 2.5 eV. At least 10 glow peaks are observed between 50 and 400 C. However, the number of peaks observed depends on the dose. Only 5 or 6 are induced by any single irradiation. All peaks can be described by first-order kinetics, but the kinetic parameters change with dose. TL measurements made after: 1) a test dose, 2) a large sensitizing dose, and 3) a second test dose shows that quartz "remembers" previous exposure to radiation.

These results, as well as previous studies with conventional TL equipment [7], can be applied to uranium exploration. The relation between an underground traverse, fault, uranium deposit and the mineral flow pattern assumed to have formed the deposit is shown in Fig. 2(a). The natural and artificial TL measured on samples obtained along the traverse is shown in Fig. 2(b). The presence of the deposit is <u>not</u> indicated by U_3O_8 measurements along the traverse. However, the TL curves show pronounced maxima at the points where the material producing the deposit is assumed to have passed through the sandstone.

THERMOLUMINESCENCE OF THERMALLY MODIFIED ALBITE

Unheated natural albite exhibits prominent radiation induced TL emission bands at 4.4 and 2.2 eV, a weak band at 3.0 eV and glow peaks near 75, 150 and 200 C [8]. The peak temperatures vary with dose and are best described by 2nd order kinetics. All of the approximately 40 peaks studied previously with the 3-D apparatus are well described by 1st order kinetics. The TL emission from unheated albite and from samples disordered by heating 48 days at 1050 C is shown in Fig. 3. Clearly the relative band intensities have been changed. With increasing disorder, as measured by x-ray techniques, the emission bands shift to longer wavelengths and widen monotonically. Heating between 600 and 800 C broadens the emission bands and alters the glow curves. In this region lattice modifications are not detected by x-rays. Thus it appears that TL can be used to defect related processes, such as a precursor to the disordering mechanism, at levels too low to be studied by x rays.

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Figure Captions

Fig. 1 (a) A 3-D plot and (b) glow peak intensity vs distance-from-ore curves for dolomite host rock, containing lead-zinc mineralization, after ^{60}Co irradiations of 10^6 R.

Fig. 2 (a) Area near underground uranium deposit at Ambrosia Lake, N.M. (b) Natural and radiation induced glow peak intensities from quartz samples obtained along traverse.

Fig. 3 3-D TL plots for albite ($NaAlSi_3O_8$), after ^{60}Co irradiations of 10^6 R, before and after heating at 1050 C for 48 days.

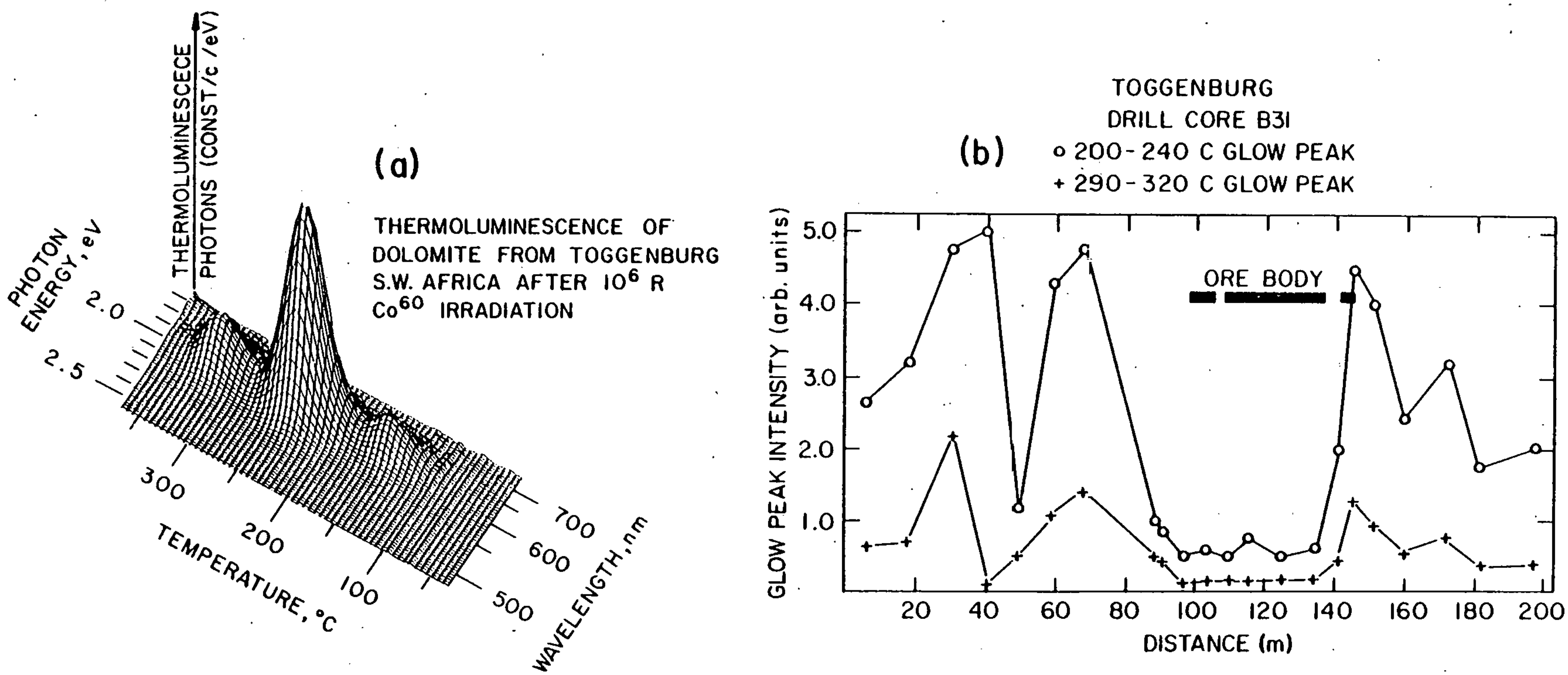
(a)
THERMOLUMINESCENCE OF
DOLOMITE FROM TOGGENBURG
S.W. AFRICA AFTER 10^6 R
Co^60 IRRADIATION
THERMOLUMINESCECE
PHOTONS (CONST/c /eV)
PHOTON ENERGY, eV
2.0
2.5
300
200
100
TEMPERATURE, °C
700
600
500
WAVELENGTH, nm
(b)
TOGGENBURG
DRILL CORE B31
o 200-240 C GLOW PEAK
+ 290-320 C GLOW PEAK
ORE BODY
GLOW PEAK INTENSITY (arb. units)
5.0
4.0
3.0
2.0
1.0
20
40
60
80
100
120
140
160
180
200
DISTANCE (m)

FIG 1

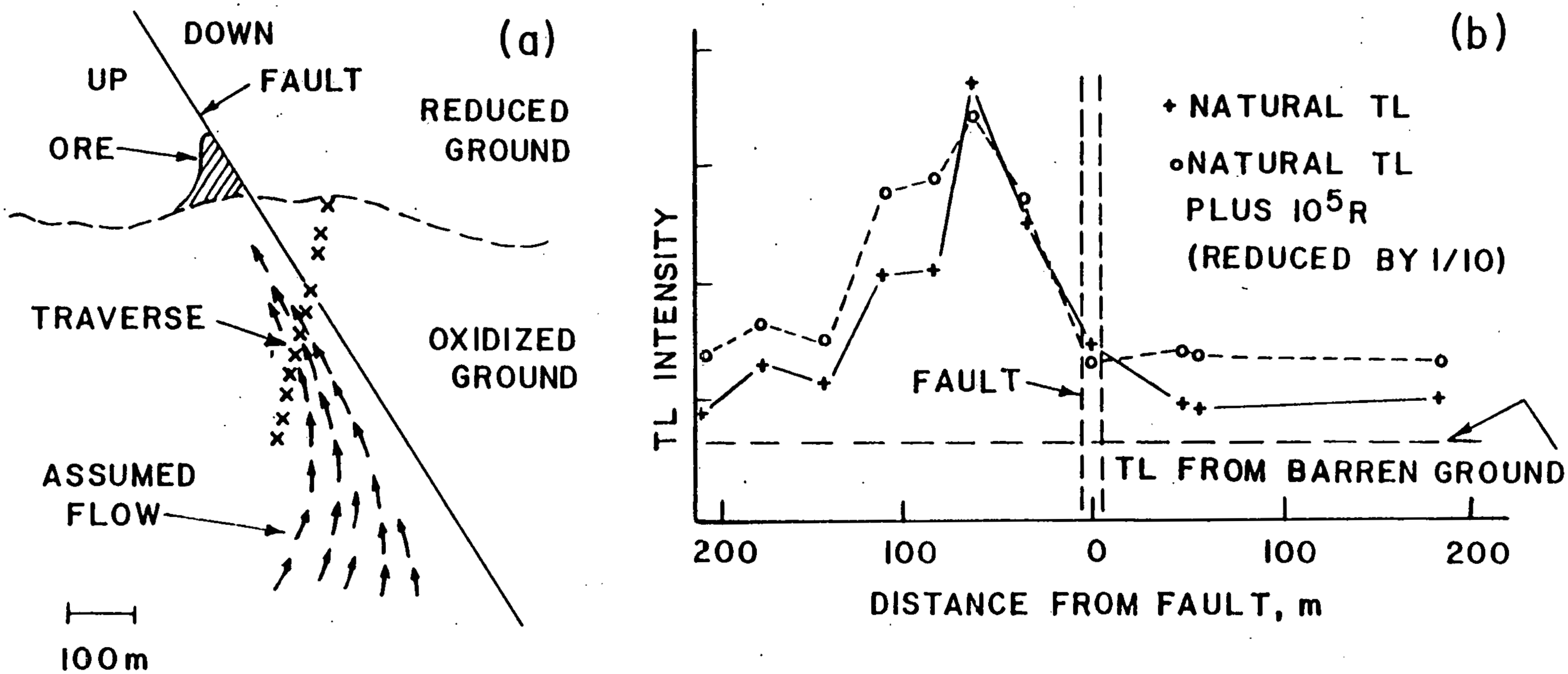
DOWN
(a)
UP
FAULT
REDUCED
GROUND
ORE
TRAVERSE
OXIDIZED
GROUND
ASSUMED
FLOW
100m
(b)
+ NATURAL TL
o NATURAL TL
PLUS 10⁵R
(REDUCED BY 1/10)
TL INTENSITY
FAULT
TL FROM BARREN GROUND
200
100
0
100
200
DISTANCE FROM FAULT, m

FIG 2

UNHEATED

MAXIMUM INTENSITY $2 \cdot 8 * 10^{6}$ (CONST/C/eV)

HEATED 48 DAYS AT 1050 C

MAXIMUM INTENSITY $7 \cdot 8 * 10^{5}$ (CONST/C/eV)

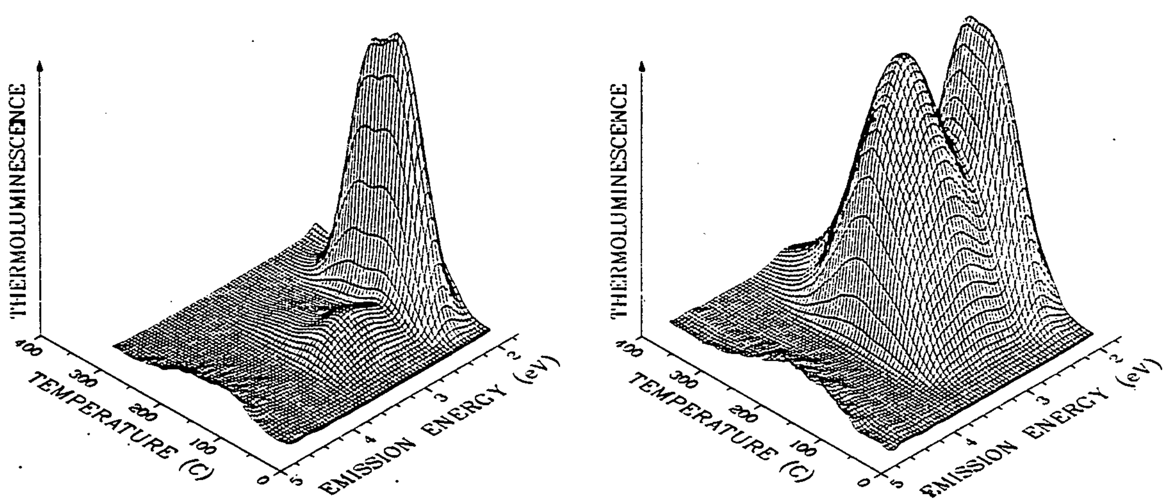

FIG 3