Site 229 was in the southernmost extension of the Red Sea rift system. The Late Quaternary section contained carbonate ooze with volcanic glass fragments and occasional ringing-hard welded tuff beds. The site was abandoned at 212 m after we had encountered increasingly gassy cores.

Only one core was recovered from site 230, owing to the inability of the *Glomar Challenger* to maintain position in adverse weather conditions at this record shallow depth (850 m). However, a 50 percent increase in the interstitial salinity at this very shallow depth allows us to conclude that the acoustic reflector here was the top of the Late Miocene evaporites as in previous sites. Previous DSDP drillings (*11*) showed that interstitial salinity gradients of the type observed here are accurate predictors of halite and other evaporites at depth beneath sediments.

DAVID A. ROSS
Woods Hole Oceanographic Institution,
Woods Hole, Massachusetts 02543
ROBERT B. WHITMARSH
National Institute of Oceanography,
Wormley, Godalming, Surrey,
United Kingdom
SYED A. ALI
Marine Sciences Research Center,
State University of New York,
Stony Brook 11790
JOSEPH E. BOUDREAUX
Texaco, Inc.,
New Orleans, Louisiana 70112
ROBERT COLEMAN
U.S. Geological Survey,
Menlo Park, California 94025
ROBERT L. FLEISHER
Department of Geological Sciences,
University of Southern California,
Los Angeles 90007
RONALD GIRDLER
Department of Geophysics,
University of Newcastle-upon-Tyne,
Newcastle-upon-Tyne, United Kingdom
FRANK MANHEIM
U.S. Geological Survey,
Woods Hole, Massachusetts 02543
ALBERT MATTER
Geologisches Institut, Universität
Bern, Bern, Switzerland
CATHERINE NIGRINI
17 Highland Avenue,
Lexington, Massachusetts 02173
PETER STOFFERS
Woods Hole Oceanographic Institution,
Woods Hole, Massachusetts 02543
PETER R. SUPKO
Scripps Institution of Oceanography,
La Jolla, California 92037

References and Notes

1. Mobile spectrographic equipment was made available by the Exploration Research Branch and the Office of Marine Geology, U.S. Geological Survey. Some 6000 semiquantitative analyses were performed on board.
2. For specifics, see E. T. Degens and D. A. Ross, Eds., ***Hot Brines and Recent Heavy Metal Deposits in the Red Sea*** (Springer-Verlag, New York, 1969).
3. Recent measurements of water temperature by Brewer *et al.* [P. G. Brewer, T. R. S. Wilson, J. W. Murray, R. G. Munns, C. D. Densmore, ***Nature*** **231**, 37 (1971)] and Ross [D. A. Ross, ***Science*** **175**, 1455 (1972)] show a 59.2°C bottom water overlain by a 49.7°C water layer in the Atlantis II Deep. The temperatures have increased from 1966 when the temperatures of the water layers were 56.5° and 44.3°C, respectively. The increase has been interpreted by the above authors as due to an input of hot water, the temperature of which was probably at least 104°C. Salinities are as high as 257 per mil. Temperature measurements made from the *Glomar Challenger* suggest a further increase in the temperature of the bottom layer.
4. H. Craig, in ***Hot Brines and Recent Heavy Metal Deposits in the Red Sea***, E. T. Degens and D. A. Ross, Eds. (Springer-Verlag, New York, 1969), p. 208.
5. J. L. Bischoff and F. T. Manheim, in *ibid.*, p. 535.
6. S. T. Knott, E. T. Bunce, R. L. Chase, *Geol. Surv. Can. Pap. 66-14* (1966), p. 33; J. D. Phillips and D. A. Ross, ***Phil. Trans. Roy. Soc. London Ser. A*** **267**, 143 (1970).
7. W. B. F. Ryan *et al.*, *Geotimes* **15** (No. 10), 12 (1970).
8. K. H. Wedepohl, *Geochim. Cosmochim. Acta* **28**, 305 (1964).
9. H. Bäcker, personal communication.
10. J. D. Phillips, J. Woodside, C. O. Bowin, in *Hot Brines and Recent Heavy Metal Deposits in the Red Sea*, E. T. Degens and D. A. Ross, Eds. (Springer-Verlag, New York, 1969), p. 98.
11. F. T. Manheim and F. L. Sayles, *Science* **170**, 57 (1970), and references therein.
12. The bathymetry of the Rea Sea was determined by A. S. Laughton [*Phil. Trans. Roy. Soc. London Ser. A* **267**, 21 (1970)]. The bathymetry of the hot brine area was determined by D. A. Ross, E. E. Hays, and F. C. Allstrom [in *Hot Brines and Recent Heavy Metal Deposits in the Red Sea*, E. T. Degens and D. A. Ross, Eds. (Springer-Verlag, New York, 1969), p. 82].
13. The Deep Sea Drilling Project is financed by the National Science Foundation and managed by Scripps Institution of Oceanography for JOIDES, the Joint Oceanographic Institutions for Deep Earth Sampling. We thank the officers, crew, and technicians aboard *Glomar Challenger* leg 23B. This report was reviewed by J. C. Hathaway and K. O. Emery. Woods Hole Oceanographic Institution contribution No. 2868.

11 September 1972; revised 15 November 1972 ■

Radiation Dosimetry by a New Solid-State Effect

Abstract. *Ionizing radiation can induce strong electrical polarization phenomena in dielectic solids. These radiation-induced thermally activated depolarization (RITAD) effects are quite different from radioelectret effects. For nominally pure calcium fluoride samples, the RITAD signals show a signal-to-noise power advantage of 40 decibels over that of thermoluminescence signals measured under the same experimental conditions. Ease of measurement, very high radiation sensitivity, and simple sample fabrication requirements give the RITAD phenomena a great potential for use as a new solid-state dosimetry technique.*

It has been reported (*1*) that a stable electrical polarization is induced when high-purity LiF is exposed to ionizing radiation in the presence of an externally applied electric field. We now report a much stronger effect observed in a variety of dielectrics; in the absence of any external field during either radiation exposure or readout, small doses of ionizing radiation produce a very intense polarization phenomenon. This effect occurs along the sample's internal local fields, which were earlier produced by a high-temperature bias-polarization procedure, which we shall describe later. The effect is easily measured by shorting the sample's sensing electrodes through a picoammeter, heating the sample through a characteristic temperature to produce thermally activated depolarization, and recording the depolarization current thus generated. The physical origins of the phenomena reported here are clearly different from those responsible for various radioelectret effects (*2–4*) such as occur in thermal electret-forming materials, for example, in Teflon or carnauba wax. We have been unable to detect any thermal electret-like activity in our unirradiated samples in the temperature ranges characterizing the activated depolarization subsequently induced by irradiation. Consequently, we call the effects we report here by the general description "radiation-induced thermally activated depolarization" (RITAD). External RITAD phenomena are generated in an externally applied electric field and differ from the more sensitive local RITAD phenomena generated in the sample's local fields.

Local RITAD shows very high radiation sensitivities. For example, although CaF$_2$ is used (*5*) as one of the most sensitive thermoluminescence (TL) dosimetry phosphors, we have observed RITAD signals in CaF$_2$ showing, to our astonishment, at least a 40-db advantage in the signal-to-noise power ratio over that of the TL signals mea-

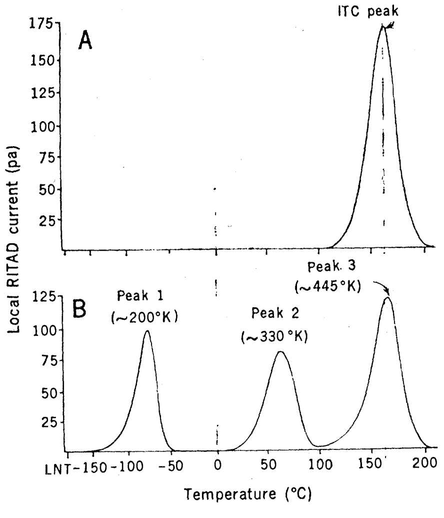

Fig. 1. Thermally activated depolarization curves for the local RITAD effect in CaF$_2$; *LNT*, liquid nitrogen temperature. (A) The sample is subjected to a bias-poling procedure but not irradiated. (B) The sample is bias-poled and exposed to 40 roentgens of 35-kev effective x-rays.

sured under the same experimental conditions. We have seen some degree of RITAD activity in many host materials, for example, the alkaline-earth fluorides, human bone, natural apatite containing halogens, alumina ceramics, and alkali halides. Details of this finding will be presented elsewhere (*6*), and in this report we outline only the basic results on the first material studied, CaF$_2$.

The research samples we used were optical quality high-purity CaF$_2$ crystals (Harshaw, batch 1970) cleaved to a cross section of 1 by 0.5 cm with a thickness of 0.15 cm. Thin sensing electrodes are attached to the cross-section faces; neither the type of contact, nor the type of electrode material, nor the specific electrode geometry affects the observed RITAD behavior. To produce the local RITAD effect, one first activates a bias-polarization; for CaF$_2$, the crystal temperature is raised above 230°C and one applies an electrode bias-poling voltage. The best sensitivity for bias-poling voltages occurs above about 1000 volts. Next the cooling system of the sample chamber is activated to lower the temperature rapidly. Below about 100°C, the poling voltage can be removed and the electrodes shorted out. As a result of this treatment the sample retains a very strong electret polarization; this is probably related to states which Bucci and his collaborators (*7, 8*), working with other impurity-doped materials, have called the "dielectric catastrophe" ionic thermocurrent (ITC) bands. Our results indicate, however, that our bias-polarization state is a stable and experimentally reproducible, thermally activated, volume polarization property of dielectrics characterized by uniformly distributed traces of charge-compensated impurities, rather than by the contact, surface polarization or dislocation-linked ITC phenomena (*8*) observed by others. We believe this bias-polarization state produces the local electric field necessary in order that one observe the local RITAD effect after subsequent irradiation. If an unirradiated sample is heated after the bias-poling procedure, only the ITC state depolarization current is observed at high temperatures, as shown in Fig. 1A.

If the same sample is bias-poled a second time and, at some later time, exposed to ionizing radiation, new depolarization bands, local RITAD states, appear. This is indicated in Fig. 1B for x-ray exposure at 77°K and a temperature scan of 0.5°K sec^{-1}. The exposure in Fig. 1B corresponds to about 40 roentgens of x-rays (85-kv peak) filtered to give an effective (*9*) photon energy of 35 kev at the CaF$_2$ sample; the corresponding dose conversion is about 10 rads per roentgen. We call the 200° and the 330°K local RITAD peaks the "dosimetry peaks" because they grow from zero intensity with increasing radiation exposure. The 445°K peak is the remnant of the bias-polarization ITC state induced by the bias-poling process. It alone exhibits similarities to reported radioelectret behavior; once the sample is bias-poled, the intensity of this peak decays with increasing radiation dose, and the peaking temperature at a given scan rate increases with dose. Figure 2 shows the local RITAD intensity as a function of exposure for a bias-poling voltage of 1200 volts and an irradiation rate of 0.75 roentgen sec^{-1}; other experiments indicate no observable rate dependence. The time breadth of the local RITAD peaks is about 70 seconds at our scan rate.

In the linear growth region, the radiation response of the local RITAD dosimetry peaks is about 4×10^{-10} coulomb cm^{-2} roentgen^{-1}, which can be compared, for example, to the radioelectret effect response reported for Teflon (*3*) of about 5×10^{-15} coulomb cm^{-2} roentgen^{-1}. The local RITAD signals, in addition, are very noise-free. Murphy *et al.* (*4*) reported for the total charge release a 40 : 1 signal-to-noise ratio against background for the Teflon radioelectret effect at an exposure of about 10^7 roentgens, whereas our experiments on the local RITAD effect indicate a signal of similar quality for an exposure of about

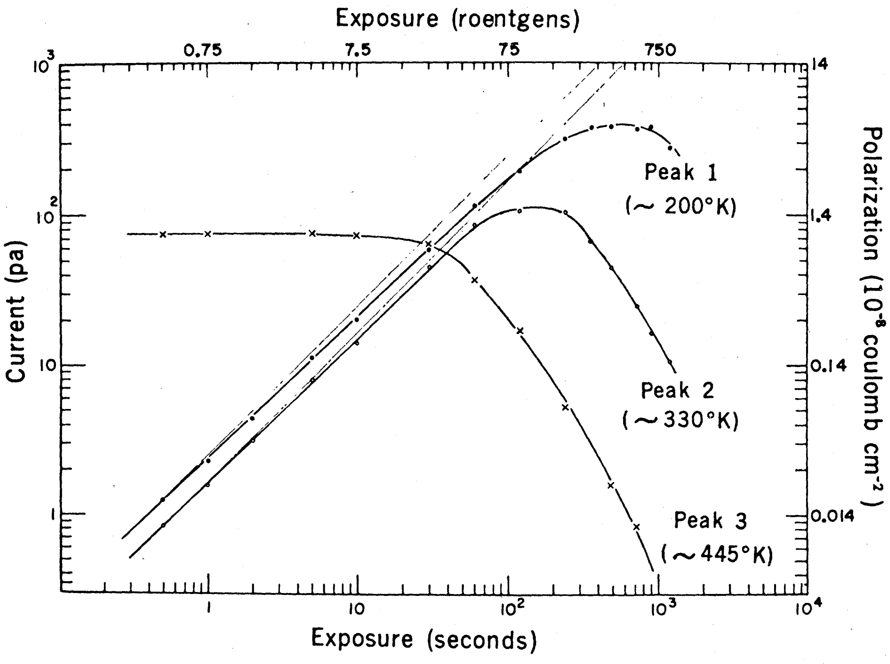

Fig. 2. Depolarization current versus radiation exposure for the dosimetry peaks at 200° and 330°K, and for the bias-polarization ITC peak at 445°K.

10^{-3} roentgen. Although not specially doped for optimum high-temperature TL efficiency, our CaF_2 samples show reasonably intense TL peaks at low temperatures. At exposures above 100 milliroentgens the measurement precisions of both the local RITAD current and the TL photomultiplier current are limited by shot noise (signal fluctuation due to the discrete nature of the entities being measured). For the same samples, the same exposure, and the same electronic instrumentation, the signal-to-noise power ratio of the local RITAD current readout is at least 40 db greater than that for the most sensitive TL peak signal. The 200°K local RITAD peak is closely correlated with a corresponding TL peak, but the 330°K RITAD dosimetry peak falls near a minimum within a group of three incompletely resolved TL peaks characteristic of these CaF_2 samples.

For exposures below 100 milliroentgens the measurement precision of the RITAD current becomes limited by the instrumental noise of our present system, which has a noise figure (ratio of the instrument's actual output noise to the theoretical minimum noise arising from thermally generated fluctuations in the resistive elements) in excess of 20 db. In spite of such poor electronic performance, however, and an unnecessarily large instrument bandwidth of about 1 hertz (that is, a rise time of ~ 0.15 second), the local RITAD signal-to-noise ratio is about 200 : 1 for a 75-milliroentgen exposure. Integration over about 100 seconds to obtain the total charge release, even without any improvement in the existing dosimeter geometry or instrumentation noise figure, gives a 6000 : 1 signal-to-noise ratio on the RITAD charge output at 75-milliroentgen exposure.

We do not understand, as yet, the detailed mechanisms producing the local RITAD effects, except that they seem to be generated by the thermally activated mobility of trapped electrons or holes, or both. There are two possible explanations. According to the first explanation, during irradiation the transient mobility of electrons and holes allows them to separate in the bias-polarization field, leading to a frozen-in transportative polarization (polarization attributable to charge transport); during subsequent thermally induced mobility, the recombination of electrons and holes produces the RITAD depolarization signal. According to the second explanation, trapped electrons and holes are formed with an essentially uniform spatial distribution during irradiation; during readout, however, thermally activated mobility allows the detrapped carriers to drift without total recombination and to produce the RITAD signal as they attempt to depolarize the preexisting bias-polarization state. Our experiments indicate that both processes may simultaneously occur in the observed RITAD phenomena.

The particular CaF_2 RITAD states described here can be utilized for some special-purpose dosimetry techniques, for example, fast neutron activation dosimetry. Unfortunately, they fade too rapidly to be really practical for use in routine room-temperature dosimetry. The principle, however, is clearly established. Our preliminary work on SrF_2 shows a local RITAD peak occurring at a temperature about 40°K higher than the CaF_2 peak 2. We believe that the local RITAD properties described above, namely, high radiation response, low intrinsic noise, the absence of any requirements for good optical quality crystals, the absence of any necessity for electrical conductive integrity of the sample, the flexibility of dosimeter fabrication, and the simplicity of readout, ensure a very great potential for local RITAD phenomena as an important new technique in sensitive radiation dosimetry.

ERVIN B. PODGORŠAK
P. R. MORAN

*Department of Physics,
University of Wisconsin,
Madison 53706*

References and Notes

1. D. E. Fields and P. R. Moran, *Phys. Rev. Lett.* **29**, 721 (1972).
2. M. Eguchi, *Phil. Mag.* **49**, 178 (1925).
3. G. G. Wiseman and G. R. Feaster, *J. Chem. Phys.* **26**, 521 (1957).
4. P. V. Murphy, S. C. Ribeiro, F. Milanez, R. J. de Moraes, *ibid.* **38**, 2400 (1963).
5. E. Okuno and S. Watanabe, in *Proceedings of the Third International Conference on Luminescence Dosimetry* (Risø, Roskilde, Denmark, 11–14 October 1971) (Gjellerup, Copenhagen, 1971), Risø Report 249, part 2, p. 864; C. M. Sunta, *ibid.*, Risø Report 249, part 1, p. 392.
6. E. B. Podgoršak and P. R. Moran, in preparation.
7. C. Bucci and R. Fieschi, *Phys. Rev.* **148**, 816 (1966).
8. S. Benci, C. Bucci, R. Cappelletti, R. Fieschi, C. Paracchini, L. Pirola, *Final Sci. Rep. Air Force Eur. Off. Aerospace Res. 65–07* (U.S. Air Force Office of Aerospace Research, Washington, D.C., 1968).
9. H. E. Johns and J. R. Cunningham, *The Physics of Radiology* (Thomas, Springfield, Ill., ed. 3, 1969), p. 256.
10. We thank Drs. J. R. Cameron and J. Wanger for helpful discussions. Supported by the University of Wisconsin Graduate School.

15 September 1972; revised 8 November 1972 ■

Blue-Green Algae: Why They Become Dominant

Abstract. *The injection of carbon dioxide and the addition of nitrogen and phosphorus to a lake population dominated by blue-green algae results in a rapid shift to dominance by green algae. The basis for the change and its implications are discussed.*

Possibly the most perplexing problem presently facing limnologists concerns the relative abundances in lakes of various types of algae. This is particularly true for certain of the blue-green algae, which have earned the sobriquet "nuisance algae" because they are extremely abundant and dominant in situations where nutrients are plentiful, and which usually become dominant when nutrient inputs increase. A variety of hypotheses have been proposed ranging from the suggestion that blue-green algae are symbiotic with bacteria that abound under such enriched conditions to the supposition that blue-green algae require the organic compounds that enter lakes with high concentrations of nutrient wastes, such as domestic sewage effluents. However, none of these hypotheses has been given confirmation and the problem persists. Recently, King (*1*) suggested an explanation that is not only apparently supported by the facts but that is also experimentally testable. Using his own data and those from the literature, King suggested that blue-green algae are more efficient at obtaining CO_2 from low concentrations than green algae, and that under circumstances when the *p*H is high, as in enriched lakes, blue-green algae should predominate.

My tests of this hypothesis were direct. I subjected a mixed population of algae under conditions as natural as possible to a variety of treatments including high concentrations of nutrients (nitrogen plus phosphorus), high concentrations of CO_2, and high or low *p*H (5 to 6). The experiments were carried out in duplicate in a series of 12 polyethylene bags, each 1 m in diameter and 1.5 m deep, suspended from a raft