cm interval contain appreciable amounts of shale and rock fragments reduced to various particle sizes by the grinding action of glaciers. These components contain isotopically heavy kerogen which must constitute an appreciable fraction of the total kerogen. One may estimate the amount of this contribution by using an expression which relates the percentage of carbon and the $\delta^{13}C$ values of each component and the fraction (F) of recycled material, for example,

$$[(\%C)(\delta^{13}C)]_T = F[(\%C)(\delta^{13}C)]_R \times \{(1-F)[(\%C)(\delta^{13}C)]\}_A$$

where the subscript T refers to the total fine fraction, the subscript R refers to recycled material, and the subscript A refers to authigenic material. Using values of 0.7 percent and − 27.2 per mil, respectively, for the amount and isotopic composition of the authigenic material and 0.23 percent and −22.3 per mil, respectively, for average values of the coarse material for the 20- to 35-cm sections, the fine fractions of the 20- to 25-cm, 25- to 30-cm, and 30- to 35-cm intervals contain 85, 86, and 90 percent, respectively, recycled kerogen. These estimates are only approximate as the $\delta^{13}C$ compositions of the coarse fractions are quite variable. It is only because some of the coarse fractions in this core have anomalously heavy isotopic values that the kerogen contribution is recognizable.

Two other cores taken toward the eastern side of the ice shelf have $\delta^{13}C$ values of − 25.9 and − 26.1 per mil at the top, with an abrupt decrease to a rather constant − 24.5 ± 0.5 per mil down the remainder of the cores. Presumably the recycled kerogen in these sediments is not isotopically heavy, or the amounts are relatively small or constant, or both, for each interval.

We believe that the results reported here are important in providing real evidence that kerogen is being recycled. With the development and use of the new and more sophisticated chemical techniques for studying organic matter in marine sediments, it is important for geochemists to recognize early in their investigations that in one sediment sample they may be dealing with several types of kerogen originally produced at different times and in different environments.

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$$\delta^{13}C = \left(\frac{^{13}C/^{12}C_{sample}}{^{13}C/^{12}C_{PDB}} - 1\right) 1000$$

where PDB is the Pee Dee belemnite standard.
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Earthquake Prediction: Absence of a Precursive Change in Seismic Velocities before a Tremor of Magnitude 3¾

Abstract. P-*wave velocities in the region near the source of a tremor of magnitude 3¾ were constant to within 2 percent for 41 days before the event; no evidence of a precursive change in velocity was found. Observations of* S-*wave velocities and the ratio of* P-*wave to* S-*wave velocities also showed no precursive changes. In recent studies, premonitory changes in body-wave velocities of about 10 percent and having a duration of 2 to 3 weeks have been reported for crustal earthquakes of this size.*

Premonitory changes in the ratio V_P/V_S (*P*-wave velocity/*S*-wave velocity) have been reported for earthquakes in the Garm region of central Asia (*1*), the Adirondack region of New York State (*2*), and southern California (*3*). Typically V_P/V_S is reported to diminish by about 10 percent below its usual value for a certain length of time and then reattain its normal value shortly before an unusually large earthquake. Whitcomb *et al.* (*3*) reported that V_P/V_S diminishes primarily because of a diminution of about 10 percent in V_P.

On 27 March 1973 at 00:48 G.M.T. an unusually large tremor, of magnitude 3¾ (*4*), occurred in the eastern section of East Rand Proprietary Mines (ERPM), 24 km east of Johannesburg, South Africa. The hypocenter of the event was located by using an underground array of ten geophones (*5*) and was found to be about 3 km below the surface and about 150 m above the edge of a mined-out area; the event occurred near the margin of the underground seismic array, and the uncertainty in the hypocentral location is about 100 m. This tremor caused extensive damage underground within a radius of more than 1 km (*6*) and was felt throughout the general Johannesburg area.

According to Whitcomb *et al.* (*3*) the duration of the precursive anomaly in V_P/V_S is related to the magnitude by log $t = 0.68M - 1.31$, where t is in days. Thus, a precursive anomaly lasting about 17 days would be expected for the event of 27 March.

In the first half of 1973 the Bernard Price Institute of the University of the Witwatersrand, Johannesburg, was engaged in a detailed study of seismicity and tilt in a region about 200 by 350 m in area, 3.1 km below the surface, and 1.2 km west of the focus of the large tremor; this region is referred to as region A. Tremors in region A, ranging in magnitude from −1 to 2.2, served as seismic sources for measuring V_P and V_S in the source region of the tremor of 27 March.

Figure 1 shows the locations of the hypocenter of the large tremor, region A, and six geophones of the underground seismic array. Seismic velocities were monitored along the ray paths from region A to the geophones labeled 42SEV and 58K; hypocentral distances to region A, 42SEV, and 58K are 1.2, 1.1, and 0.7 km, respectively.

The approximate source dimension of the event of 27 March is 3.2 km, so region A and stations 42SEV and 58K are all within the source dimension of this event (*7*).

Figure 2A shows V_P measured over ray paths between region A and stations 42SEV and 58K from 41 days before 27 March to 2 days after. Measured over the ray path to 42SEV, V_P

is 6.16 km/sec, constant within 2 percent, and over the path to 58K it is 5.94 km/sec, constant within 3 percent. It is clear from Fig. 2A that there is no anomaly in V_P with a duration of 2 or 3 weeks.

Measurements of V_S over the two ray paths are shown in Fig. 2B. For the path to 42SEV V_S is essentially constant at 3.78 km/sec with scatter in the data about this value of 6 percent. To 58K V_S is constant at 3.91 km/sec with 4 percent scatter. Most of the scatter in Fig. 2B is probably due to uncertainty in determining *S*-wave arrival times in the presence of *P*-wave coda.

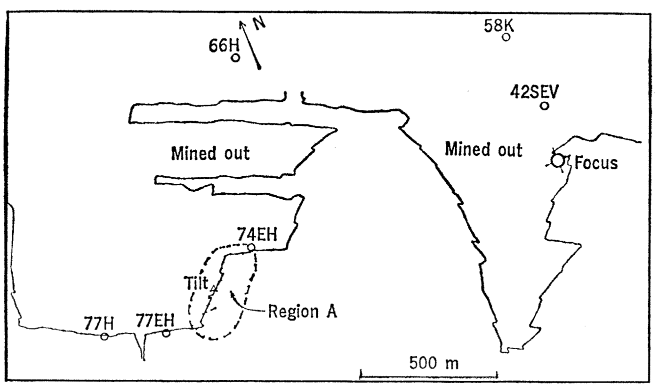
Values of V_P/V_S, as seen in Fig. 2C, also appear to be stationary in time, with random scatter primarily due to uncertainty in V_S. For ray paths to 42SEV V_P/V_S has a mean of 1.63, and for paths to 58K the mean is 1.52 (*8*).

The tremors in region A were located by measuring arrival times of *P* waves at a minimum of six geophones and then determining focal coordinates that were most consistent with the observations (*5*); for the month of March nearly all events were located on the basis of *P*-wave arrival times at a minimum of eight geophones, so there was considerable redundancy in these locations. Compressional velocities to all the geophones were measured directly by means of large calibration explosions detonated in region A. The dimension of 1 second on the seismogram is 100 mm, so an uncertainty in timing of less than 2 msec was easily achieved. The uncertainty in seismic locations was found to be about 20 m in plan and 30 m in depth, or a total uncertainty of about 35 m (*9*). One of the calibration explosions in region A was detonated on 23 March 1973, and values of V_P for paths to 42SEV and 58K were found to be within 1 percent of the average values of Fig. 2A.

The scatter in the measurements of V_P (Fig. 2A) is due almost entirely to uncertainty in hypocentral locations. The length of the ray path from region A to 42SEV ranges from 1800 to 1900 m; a location uncertainty of 35 m is equivalent to an uncertainty of about 2 percent in the length of the ray path or, equivalently, in the determination of V_P. Similarly, the distance from region A to 58K is about 1500 m, and a 35-m uncertainty in the length of the ray path is equivalent to about 3 percent uncertainty in V_P.

In summary, the data in Fig. 2 show no time dependence in V_P or V_S; all variations can be accounted for by uncertainties in the measurements (*10*).

According to the model of rock dilatancy and water diffusion as precursive phenomena associated with earthquakes, the change in V_P/V_S is due, in part, to the formation of cracks in the rock in response to an increase in stress (*11, 12*). Anderson *et al.* (*12*) state that "we expect the orientation of the cracks to be controlled by the orientation of the principal stresses." If we assume planar cracks, the most likely orientation is that for which the normal to the plane of the crack is parallel to the direction of the minimum principal stress, σ_3. Thus, *P* waves that propagate parallel to the direction of σ_3 would presumably be slowed down most by crack formation, and *P* waves whose ray paths are parallel to the plane defined by the directions of the maximum and intermediate principal stresses, σ_1 and σ_2, would be relatively unaffected. Measurements of the undisturbed stress field in ERPM (*13*) showed that the directions of σ_1, σ_2, and σ_3 are (204°, 67°), (316°, 9°), and (50°, 21°), respectively, where the first term of each pair is the azimuth and the second is the angle of inclination from the horizontal. The directions of typical ray paths from region A to 42SEV and to 58K are (83°, 48°) and



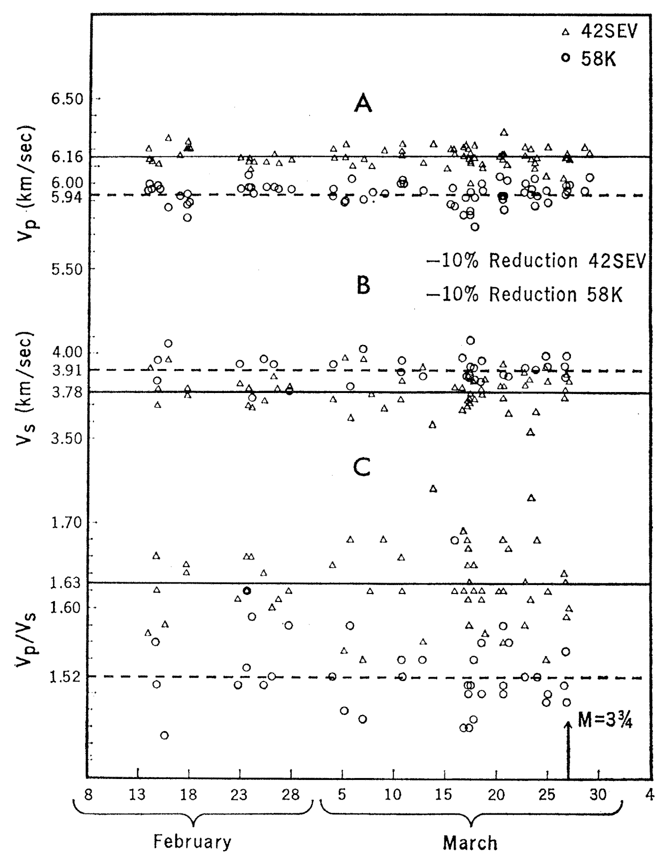


Fig. 1 (left). Plan view of a portion of the East Rand Proprietary Mines that includes the focus of the large tremor of 27 March 1973 and six of the closest geophones in the underground seismic array. The depths below surface of geophones 42SEV, 58K, 66H, 74EH, 77H, and 77EH are 1800, 2440, 2784, 3160, 3492, and 3292 m, respectively. The tiltmeter (*Tilt*) is at a depth of 3194 m, and the focus of the tremor of 27 March was 2850 m below the surface. Fig. 2 (right). Measurements of V_P, V_S, and V_P/V_S as a function of time for ray paths from region A to 42SEV and 58K. Points corresponding to reductions in V_P of 10 percent for the two paths are shown near the top. There are some gaps in the data where the seismic array was not sufficiently functional for limited periods. The *S*-wave data are somewhat sparser than the *P*-wave data since *S* arrivals cannot be measured on the underground array for events of magnitude 1 and larger because of the presence of the *P*-wave coda.

(70°, 31°), respectively. The angle between the path region A–42SEV and the direction of σ_3 is 38°, and that between the path region A–58K and the direction of σ_3 is 20°. Thus, if cracks formed in response to the tectonic stress field, the experiment reported here was appropriate for detecting their effect on V_P.

As a further check of the possibility that the ray paths considered here might not have been suitable for detecting precursive changes in seismic velocities, V_P for paths from region A to geophones 66H and 68H were measured (in Fig. 1 geophone 68H would plot slightly north of the upper left corner); both paths are also within the source dimension of the tremor of 27 March. Between 8 February and 30 March, V_P for the path to 66H was 6.04 km/sec, within 4 percent, and V_P for the path to 68H was 6.00 km/sec, within 2 percent. The scatter in V_P about the mean values for these two paths appeared random and did not suggest any precursive changes (*14*).

In most respects tremors induced by mining at depth appear to be identical to natural crustal earthquakes (*7, 15*), so it is somewhat disturbing to find that a prediction scheme reported for at least a certain class of earthquakes (*16*) is not of any use for mine tremors. There are, however, some differences between the situation of the event reported here and those of the three regions where anomalies in V_P/V_S have been documented. First, all shocks for which precursive changes in V_P/V_S have been reported have had focal mechanisms of the thrust-fault type. At ERPM the predominant mode of failure is normal faulting (*17*). Initial motions of *P* waves for the event of 27 March are appropriate for normal faulting.

Second, strain rates associated with the seismicity at ERPM are about 10,000 times greater than geological strain rates. Typical strain rates in the seismic regions of the mine are 10^{-5} day^{-1}, whereas normal geological rates are 10^{-6} year^{-1} or less. At present, the effect of strain rate on precursive changes in V_P/V_S is not known.

Third, the rock at ERPM is largely devoid of groundwater at depths greater than 1 km; there are a few fissures in the mine where groundwater percolates deeper, but these are rare. Explanations that have been presented for the precursive changes in V_P/V_S are based on the effect of dilatancy in the presence of groundwater; V_P is reduced at the onset of dilatancy and then resumes its normal value before the earthquake when groundwater flows into the hypocentral region to fill the voids. Although there is no appreciable groundwater at ERPM, one might expect to observe a reduction in V_P due to large-scale dilatancy.

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8. The values of V_P/V_S in Fig. 2C are considerably lower than the normal values of 1.75 found in New York State and southern California. The reason for these unusually low values is that Poisson's ratio, γ, for the quartzite at ERPM is very low. Laboratory measurements of γ for quartzite similar to that along the ray paths to 42SEV and 58K typically give a value of 0.16 [E. R. Leeman, *J. S. Afr. Inst. Min. Met.* **65**, 254 (1964); in *Rock Mechanics and Strata Control in Mines* (South African Institute of Mining and Metallurgy, Johannesburg, 1965)]. Values of γ inferred from V_S/V_P for ray paths to 42SEV and 58K are 0.20 and 0.12, respectively.
9. Seismic locations are calculated primarily from *P*-wave arrival times at the four geophones closest to a particular hypocenter. Arrival times at the further geophones, including 42SEV and 58K, are used mostly to check the precision of a location. The distances to the four geophones nearest to region A (Fig. 1) are so small that changes in compressional velocity of 10 percent or less would have very little effect on the seismic locations. Thus, the hypocentral coordinates in region A are, to a large extent, independent of seismic velocities along the ray paths region A–42SEV or region A–58K.
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18. I thank L. O. Nicolaysen and R. W. E. Green for reviewing the manuscript, D. L. Anderson and J. H. Whitcomb for a preprint of their paper, and J. Walsh for stimulating discussions. Suggestions by an anonymous referee are gratefully acknowledged. Supported by the South African Chamber of Mines.

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Reoviruslike Agent in Stools: Association with Infantile Diarrhea and Development of Serologic Tests

Abstract. *Reoviruslike particles were visualized by electron microscopy in stool filtrates prepared from stools of infants and young children with severe acute gastroenteritis. Patients who had such particles in their stools and whose paired acute and convalescent serums were tested developed an antibody response to the reoviruslike agent, which was measured by immune electron microscopy and by complement fixation. The reoviruslike agent was antigenically related to the epizootic diarrhea of infant mice virus and the Nebraska calf diarrhea virus.*

Recent studies by Bishop *et al.* (*1*) in Australia, Flewett *et al.* (*2*) in England, and Bortolussi *et al.* (*3*) in Canada have suggested that an orbiviruslike or a reoviruslike particle might be an important etiologic agent of acute nonbacterial gastroenteritis of infants and young children. The group of investigators in Australia demonstrated the presence of the agent by electron microscopy in epithelial cells of duodenal mucosa, and all three groups observed it by electron microscopy in fecal extracts. In addition, the investigators in Canada also found the agent in duodenal fluids. Utilizing the technique of immune electron microscopy (IEM) in which convalescent