important minor constituent of the early terrestrial atmosphere.

The correlation of radical ratios at equilibrium with the amino acid ratios after quenching was merely indicative of the type of processes operative in the shock tube. The recombination reactions involve several steps, presumably in a chain mechanism, and no simple bimolecular process is to be inferred from this correlation.

As to the accumulation of shock-produced amino acids in the oceans, a layer of water 1 m deep will become a $5 \times 10^{-6}M$ solution within 1 year without photolysis. If thicker layers of water are involved and the solution is homogeneous, the concentration will decrease linearly with depth. However, the photolysis will also decrease, exponentially with depth, because ultraviolet absorption becomes very great at some tens of meters depth in pure water, and at shallower depths when we allow for ultraviolet-absorbing solutes (*4*). Even with a residence time in the deep oceans of only a few thousand years, the expected concentration will be some orders of magnitude higher than the yearly accumulation of some 10^{-6} mole per liter. Thus a fairly high concentration of organic material will exist for further evolution in the oceans and shallow pools of the primitive earth.

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Tidal Anomalies and Regional Geological Structure

In a recent report, J. T. Kuo *et al.* (*1*) gave some results of tidal gravity measurements made at nine different stations across the United States. As one of their conclusions, they stated, "There is no observable correlation between tidal gravity parameters and the regional geology." This conflicts with results obtained in Belgium (*2*), Italy (*3*), Switzerland (*4*), and other countries. Where observations have been made at fairly close stations, the relationship between tidal anomalies and regional geological structure is obvious.

In the case of the U.S. stations, observed and calculated values for M_2 and O_1 constituents show a certain degree of correlation, but there are still sizable differences. Observed values can be either greater or smaller than calculated values, with the maximum difference of $\Delta\delta$ slightly exceeding 3.0 percent for M_2 and being about 4.0 percent for O_1. Observed values of $\Delta\delta$ range from -3.8 to $+4.2$ percent in the case of M_2 and from -0.5 to $+4.2$ percent in the case of O_1. Therefore, the anomaly between observed and calculated values can be rated as fairly large; it represents about 40 percent of the observed range for M_2 and about 85 percent for O_1. This anomaly has been plotted in Fig. 1. A positive anomaly characterizes the Rocky Mountains, a negative anomaly is found in the Appalachian area, and the stable interior seems to be nonanomalous. A dipping anomaly gradient is found toward the Pacific; an opposite gradient occurs near the Atlantic. It would appear that an explanation of the anomalies cannot be based solely on oceanic effects but must be correlated with geological structure.

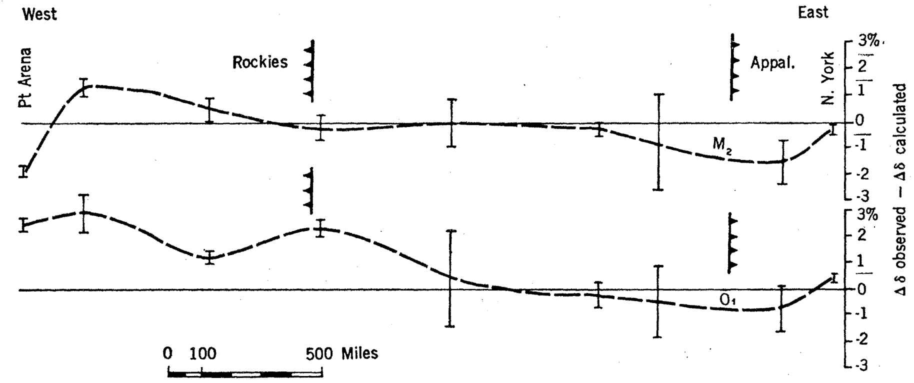

Fig. 1. Anomaly between observed and measured $\Delta\delta$ across the United States. [Data from Kuo *et al.* (*1*); 100 miles = 160.9 km]

When observed and calculated values of phase k are compared, anomalies that are very similar for M_2 and O_1 can also be detected. Slightly positive (lag) values are found over both the Rockies and the Appalachians; negative (lead) values occur over the stable interior. Anomalies range from $+0.5°$ to $-0.9°$ for M_2 and from $+0.5°$ to $-0.8°$ for O_1. Here again, it seems that oceanic effects alone cannot explain the anomalies.

It thus seems that the data obtained in the United States do show a certain correlation of earth tides with broad geological structure. It is, at present, impossible to understand fully the extent and nature of secondary geological effects. But the understanding of geological effects from static gravity measurements at nine stations across the United States would be equally difficult. With less scattered measurements, the impact of geological effects becomes more obvious. Figure 2 shows the relationship of tides measured by Melchior (*2*) and Ducarme (*5*) with geological structure.

It is therefore suggested that the extent and nature of geological effects should be investigated by observations at a number of stations which, although geographically close together, would be on definitely different structural units. In the western United States, stations equally distributed over the core of the Rockies, in their frontal thrust zone, in the foothills, and in nearby areas of the stable interior would probably prove valuable. Nearby stations on both sides of major faults should also be established (*4*).

In the past decade, an increasing number of geologists (including the late E. Marchesini) have realized that many geological lineaments could be produced mainly by tidal movements. Fracture patterns generally show one

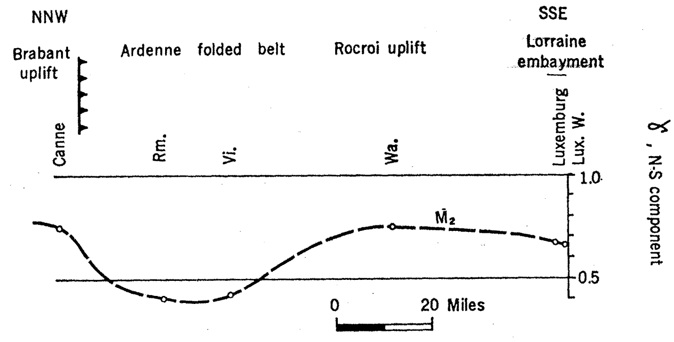

Fig. 2. Profile showing gamma values, N–S component, across southern Belgium. [Data from Melchior (*2*) and Ducarme (*5*); 10 miles = 16.09 km]

or two pairs of trends of broad regional nature, very likely due to tides, on which other trends due to local geological heterogeneities are superimposed. This is, in fact, used as a prospective tool for locating local subsurface features, such as anticlines, faults, and reefs, by the drafting of residual fracture maps.

The impact of tides on other and much broader geological processes may also be very important. It is indeed surprising to note that some major geological processes, such as sedimentation, diastrophism, erosion, and volcanicity, are cyclic in nature. They can be represented by sinusoidal curves, with larger amplitudes every so often and occasional jumps or interruptions. This pattern suggests that these processes are not entirely controlled by endogenic terrestrial forces but are also controlled to a certain extent by such factors as earth rotation and the position of the earth with respect to other astronomical bodies. The upper limit of the lithosphere is actually the surface of convergence of astronomical and terrestrial endogenic forces. From one point of view (not intended to be finalistic), it seems that every time that a certain disequilibrium is attained at the earth's surface, geological processes tend to restore equilibrium—in an amazing number of different ways. In subsident basins that are developing in an area far from clastic sources, the prevalent sedimentation consists of carbonates and evaporites, with subsequent dolomitization and dehydration. Consequently, the heavier sediments occur with a partial or total compensation of the gravity deficit. Within geosynclines, fast early subsidence is compensated by fast deposition and compaction of sediments of the "Bündnerschiefer" type. Better gravity equilibrium is often obtained by the embedding of heavy greenstone rocks. At a later stage, massive displacements of "flysch" turbidites occur. Olistostromes, glided thrust sheets, and late acid intrusives are typical of the late geosynclinal stage.

It is thus our belief that tides and, in a broader sense, astronomical phenomena should be investigated with a view to determining their effects on certain geological processes and features: in particular, rythmicity of sedimentation, distribution of densities within sedimentary embayments and igneous and metamorphic complexes, evolution of geosynclines, and block faulting. Such information would permit an assessment of the possibility of using measurements of tidal anomalies as a prospection tool, it would probably lead to a more precise definition of merely endogenic processes such as the ones now being studied in the oceans, and it might help in understanding the distribution of mineralized bodies at the earth's surface.

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We wish we could be as optimistic as Rigassi, who claims to have established such an *obvious* correlation between the tidal gravity anomalies of our measurements and the regional geological structures across the U.S. continent. Despite our preconceived notion that a correlation must exist between tidal gravity anomalies and regional geological structure, we were unable to establish a convincing correlation, as the ocean tidal conditions on open oceans are almost unknown. Although the accuracy of our measurements is about 1 percent, the calculated corrections for the effect of ocean tides on tidal gravity involve a large degree of uncertainty. Therefore, it is rather meaningless at this stage of the investigation simply to state, "A positive anomaly characterizes the Rocky Mountains, a negative anomaly is found in the Appalachian area, and the stable interior seems to be nonanomalous." Any tidal gravity anomalies that reflect the influence of regional geological structure on the U.S. continent are likely to be masked by the predominant influence of ocean tides. Apparent anomalies of both the gravimetric factors and the phases may well result from imperfect knowledge of the tidal characteristics in open oceans.

No tidal gravity measurements in Switzerland have been reported. The conflict of our results with the results obtained in Belgium, Italy, Switzerland, and other countries is really groundless. As a matter of fact, a correlation between tidal gravity anomalies and regional geological structures has never been established in these regions—nor, in fact, anywhere in the world. There are some tidal tilt anomalies that appear to correlate with local geological structures in Western Europe (*1*).

The correlation between tidal gravity anomalies (or tidal tilt and tidal strain) and regional geological structures is one of the major problems in geodynamics, which all investigators of earth tides, including the Lamont-Doherty group, are attacking today. Until the accuracy of tidal gravity measurements is better than 1 percent and until the allowance for the influence of ocean tides on tidal gravity is improved, the problem of correlation between tidal gravity anomalies and regional geological structure will remain a challenge.

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