Table 1. Chemical composition (percentages of atoms) of lunar surface at two Surveyor sites (preliminary results).

Element	Surveyor V (*1*)	Surveyor VI
C	< 3	< 2
O	58 ± 5	57 ± 5
Na	< 2	< 2
Mg	3 ± 3	3 ± 3
Al	6.5 ± 2	6.5 ± 2
Si	18.5 ± 3	22 ± 4
"Ca" *	13 ± 3‡	6 ± 2
"Fe" †		5 ± 2

* Elements having mass numbers between about 30 and 47; included, for example, are P, S, K, and Ca. † Elements having mass numbers between about 47 and 65; included, for example, are Fe, Co, and Ni. A lower limit of 3 percent "Fe" was set in the preliminary analysis of Surveyor V results (*1*). ‡ For the unresolved total of atoms with $28 < A < 65$.

mode. (The proton response from granite is not shown in Fig. 2; it is not significantly different from the lunar results.) Figure 2 demonstrates that the two lunar samples must have very similar compositions and differ from terrestrial dunites and granites.

The similarity of the results at the two Surveyor landing sites makes it improbable that the chemical composition found is applicable only to unique places on the moon. It is much more probable that they are representative of the large portions of the lunar maria that are similar in appearance and in optical and thermal properties.

Although the alpha-scattering technique provides no direct information about the chemical state of the elements identified, chemical experience indicates that the elements are combined with the oxygen that is present. The mean values given in Table 1, particularly in the case of Surveyor VI, indicate apparent deficiency of oxygen. However, well within the present limits of error, there is enough oxygen to combine with all the elements considered. Table 2 presents an example (not unique) of weight percentages of oxides that would be consistent with the analytical results from the two Surveyor missions. Such an oxide composition would imply a general chemical inertness of the lunar surface material. This inertness is consistent with the observed lack of chemical reaction with materials of the spacecraft, such as the aluminum footpads.

Table 2. An oxide composition consistent with the analytical results from Surveyors V and VI.

Oxide	Percentage by weight
Na_2O	*
MgO	5
Al_2O_3	13
SiO_2	50
CaO	15
FeO	16

* Presence of sodium has not been established with certainty; sodium oxide may be present in amounts as great as 3 percent by weight.

Table 2 illustrates the oxide composition of the bulk of the lunar material analyzed. Minor constituents, amounting to as much as 10 percent by weight, may be present. Moreover the analytical errors do not exclude the presence of some unoxidized metal or compounds decomposed by radiation. A limit to metallic iron, the most likely free metal, is placed at 0.25 percent by volume by the Surveyor magnet experiment (*5*).

It is improbable that the lunar material is a simple mixture of oxides. From our data a noncrystalline (vitreous or heavily damaged by radiation) state cannot be excluded. However, just as in terrestrial and meteoritic samples of this general composition, the oxides on the moon may be combined into more complex minerals. For example, a mixture of minerals of the feldspar and pyroxene classes is consistent with the oxide composition of Table 2. As the analytical errors are reduced and as the amounts of some of the minor constituents are established, the possible mineral composition will become more restricted. Even now the prediction of physical and chemical properties of lunar mare material, if made on the basis of known compounds and minerals consistent with the data of Table 1, should be more reliable than has been possible heretofore.

It was concluded on the basis of the Surveyor V chemical analysis (*1*) that the sample examined resembled most closely a rock of a basaltic type (a terrestrial basalt or a meteoritic basaltic achondrite). The results from Surveyor VI support this conclusion. In addition, the absolute and relative amounts of "Ca" and "Fe" determined in this mission are again most consistent with those in rocks of basaltic composition. As pointed out by Gault *et al.* (*6*), the finding of such a composition for a sample of lunar material suggests that the material is the product of cosmochemical processing such as the geologically produced differentiation of the material of the earth. The strong depletion of magnesium and enhancement of aluminum relative to silicon, in comparison with the values found in the solar atmosphere (or in chondritic meteorites or ultrabasic rocks), has been confirmed by the present results from Sinus Medii. Thus both Surveyor missions imply a chemically interesting history for lunar mare material.

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14 February 1968

Littoral of the Northeastern United States: Late Quaternary Warping

Abstract. *Isobases constructed from recently published data are strikingly parallel to both the edge of the continental shelf off the northeastern United States and the Fall Zone. Our analyses suggest that the downwarping recorded by these isobases may be explained by Daly's hypothesis of a collapsing peripheral or marginal "bulge."*

Reading of a recent paper (*1*) concerning rise in sea level and crustal warping along the northeast coast and the adjacent continental shelf of the United States suggests that closer scrutiny of the data may yield further information. The authors concluded that

> If subsidence of the New England (Atlantic) shelf and coast with respect to other areas did occur, perhaps it can be attrib-

uted to landward flow of subcrustal material required for the known uplift of the land areas after melting of their load of glacial ice.

If we had exact knowledge of the sea-level curve between 6000 and 16,000 years ago we could determine the absolute trend and form of crustal warping of the North Atlantic littoral. Unfortunately the magnitude and shape of the curve for eustatic sea level for that period is in controversy (*2*).

The crux of our argument involves the shape rather than the exact slope of the curve for eustatic sea level for the 10,000-year period commencing 16,000 years ago. If, during the Flandrian transgression, sea level fluctuated with an amplitude of some 20 m as a result of temporary regressions in the sense of Fairbridge (*3*) or of Curray (*4*), any calculation of relative deleveling of the crust would be difficult if not impossible. There are, however, few data on sea levels prior to 10,000 years ago. Fairbridge's and Curray's curves are primarily inferred on the basis of other data, especially on the marine regression that was presumably due to the readvance of continental glaciers after the Two Creeks–Alleröd interstades. Broecker and Farrand (*5*) found that the Alleröd and Two Creeks interstades did not correlate; in fact they were exactly out of phase. Furthermore Farrand notes (*6*) that a fluctuation of 18 to 25 m in sea level is equivalent to 16 to 20 percent of the total Late Wisconsin volume of glacial ice and finds no evidence of volumetric or areal fluctuations of such magnitude during the last 20,000 years.

Rather persuasive reasoning by Farrand (*6*) indicates that the rate of rise of sea level between 6000 and 16,000 years ago was nearly constant, a view sustained by Emery and Garrison (*1*). Redfield (*7*) concluded that the rate of rise of eustatic sea level on the North Atlantic littoral during the last 4000 years has been about 0.76×10^{-3} m/year, and was about 3.34×10^{-3} m/year between 12,000 and 4000 years ago. We plotted (Fig. 1) both the Redfield eustatic curve (taking the liberty of extending it to 16,000 years ago) and Emery and Garrison's sea levels and dates; also plotted are data from Kaye and Barghoorn (*8*), Bloom and Stuiver (*9*), Newman and Fairbridge (*10*), and Newman (*11*) (all appear in Table 1). If the rate of rise of sea level between 6000 and 16,000 years ago was nearly constant (fluctuating less than 5 m in amplitude), theoretically any plots of data on departing sea level from this purely eustatic sea-level curve are presumably either spurious or representative of some tectonic factor.

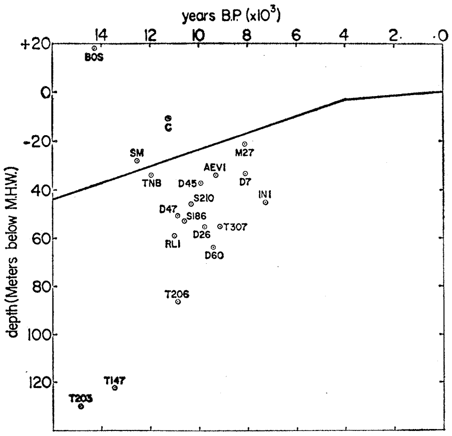

Fig. 1. Redfield (*7*) eustatic curve and plot of Emery and Garrison's (*1*) and others' (*7–11*) sea levels and carbon-14 dates for the United States North Alantic littoral. See Fig. 2 (for locations) and Table 1.

We now assume that departures from the Redfield curve represent tectonic deleveling, and are negative when below the curve and positive when above it. Such departures were plotted on a map of the area (Fig. 2) and 20-m contours were drawn connecting points of equal departure from the Redfield curve; these contours are isobases. These isobases are generally parallel to both the edge of the continental shelf and the Fall Zone. Although the values of these isobases would vary with the slope of the eustatic curve, the trend and form of warping would remain the

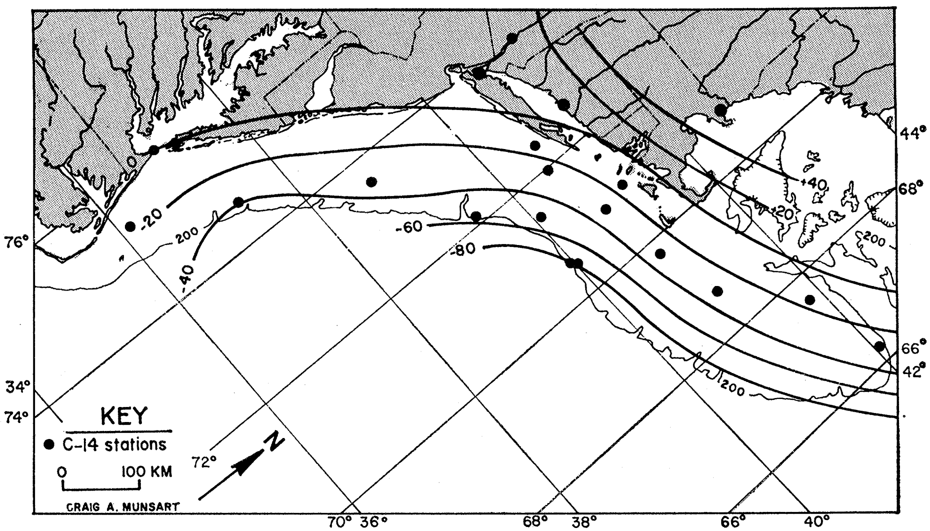

Fig. 2. Isobases (at 20-m intervals) for the United States North Atlantic littoral, based on data posted in Table 1; 200-m isobath approximates edge of continental shelf. [Redrawn from Emery and Garrison (*1*, fig. 1)]

Table 1. Radiocarbon dates for indicators of ancient sea levels, and deleveling data for the littoral of the northeastern United States (*1*, table 1 modified). Three meters were subtracted from all values of Emery and Garrison (*1*) on the assumption that the shells were deposited about 3 m below mean high water of the time; their sample T 228 is not included (*1*, p. 684).

Sample (No.)	Source coordinates (N,W)	Water depth (m)	Age (yr)	Apparent deleveling (m)	Reference
IN 1	40°59′,69°44′	45	7310 ± 300	− 28	(*1*)
D 7	36°09′,75°20′	33	8130 ± 400	− 16	(*1*)
M 27	36°59′,76°06′	21	8135 ± 160	− 1	(*1*)
T 307	40°50′,70°52′	55	9150 ± 220	− 31	(*1*)
AEV 1	41°18′,71°00′	34	9300 ± 250	− 34	(*1*)
D 60	37°24′,74°39′	64	9600 ± 600	− 40	(*1*)
D 26	38°49′,73°39′	55	9780 ± 400	− 29	(*1*)
D 45	40°43′,72°25′	37	9920 ± 400	− 11	(*1*)
S 210	41°55′,67°35′	46	10,300 ± 150	− 18	(*1*)
S 186	42°05′,67°15′	53	10,600 ± 130	− 25	(*1*)
D 47	40°40′,71°59′	51	10,850 ± 500	− 22	(*1*)
T 206	40°10′,71°26′	86	10,850 ± 150	− 56	(*1*)
RL 1	41°09′,68°43′	59	11,000 ± 350	− 32	(*1*)
C	41°16′,72°31′	11	11,240 ± 160	+ 16	(*10*)
TNB	40°48′,73°47′	34	11,950 ± 200	− 5	(*11*)
SM	41°18′,73°58′	28	12,500 ± 600	+ 4	(*12*)
T 147	40°09′,70°29′	122	13,420 ± 210	− 80	(*1*)
BOS	42°27′,70°57′	+ 18	14,250 ± 250	+ 55	(*9*)
T 203	40°06′,70°32′	130	14,850 ± 250	− 85	(*1*)

same, with the slope generally dipping toward the southeast. These isobases clearly depict some combination of upwarping toward the north (probably isostatic upwarping resulting from deglaciation) and crustal downwarping toward the southeast.

Our model is subject to one real constraint. The present position of the North Atlantic shoreline results from interaction of postglacial eustatic change and crustal movement. Late Wisconsin marine deposits are exposed at increasingly higher altitudes north and northeast of Boston; raised marine deposits are absent south and southeast of Boston. Ages of radiocarbon-dated samples from these Late Wisconsin marine deposits range from about 12,000 to 14,000 years (*5*, *12*). Since, according to the Redfield eustatic curve (Fig. 1), sea level was then 29 to 37 m lower than at present, the zero isobase or "hinge line" really belongs somewhere between our −20-m and −40-m isobases. Alternately, Curray's (*4*) approximate mean eustatic sea level, from compiled data for the period between 12,000 and 14,000 years ago, indicates that our −60-m isobase is the true zero isobase.

The data derived principally from Emery and Garrison's report disclose a pattern of downwarping of the edge of the continental block off the northeast coast of the United States. This downwarping probably does not represent a water-loading effect [as Bloom (*13*) suggested] because the Gulf Coast continental shelf has not, according to Emery and Garrison, undergone downwarping similar to that of the North Atlantic littoral. The scarcity of data from off the coasts of New Jersey, the Delmarva peninsula, southeastern Virginia, and North Carolina could permit an alternate construction of isobases: for example, the isobases near the entrance to Cheaspeake Bay might reverse themselves and thus support Daly's (*14*) original concept of a collapsing marginal or peripheral bulge analogous to the subcrustal flow suggested by Emery and Garrison.

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Prevention of Radiation-Induced Creatinuria by Insulin

Abstract. *Insulin completely suppressed creatinuria in rats x-irradiated with an absorbed dose of 500 rads. The hormone may exert this effect either by restoring or maintaining the ability of irradiated muscle to take up creatine from the extracellular fluid at a normal rate, or possibly by influencing the synthesis or breakdown of phosphorylcreatine.*

Previous studies have shown that animals exposed to x-irradiation exhibit a profound creatinuria (*1*). The creatinuria is dose dependent (*2*) and is maximal between the 2nd and 4th days after a single whole-body exposure. According to the current concept of creatine metabolism, radiation-induced creatinuria may be caused by any one or a combination of the following conditions: (i) increased release of creatine from damaged muscle or other organs; (ii) impaired uptake of creatine by muscle; (iii) increased rate of creatine synthesis; (iv) decreased rate of conversion of creatine to phosphorylcreatine or creatinine or both; and (v) impaired kidney function. The recent work of Gerber *et al.* (*3*, *4*) indicates that radiation-induced creatinuria results, at least in part, from a failure of muscle to utilize newly synthesized creatine at a normal rate. Furthermore, it appears that the defect in the ability of skeletal muscle to take up creatine from the blood is in part a result of direct damage to muscle caused by the incident radiation and is partially an indirect effect of x-irradiation (*5*). Although the possibility that radiation-induced creatinuria is mediated by irradiation of the adrenal (*6*) or the thyroid-parathyroid glands (*7*) appears to be excluded, it is not known if other endocrine glands are involved.

Conn (*8*) has reported recently that insulin, added to an in vitro system, enhanced the activity of highly purified creatine phosphokinase. This observation, as well as other observations made over 20 years ago, namely, that insulin promotes phosphorylcreatine synthesis in normal (*9*) and alloxan-diabetic animals (*10*), suggests that this hormone may play a role in the regulation of creatine metabolism. These considerations prompted us to study the effect of insulin on radiation-induced creatinuria, a condition which reflects a gross derangement of normal creatine metabolism.

Male rats of the Wistar strain, weighing 135 to 145 g, were caged individually in metabolism cages. The rats fed freely on Purina Laboratory Chow and were given water to drink. After a 2- to 3-day equilibration period, urine was collected daily, filtered, and then was frozen and stored at −15°C. On the 4th day, one group of rats was x-irradiated with a whole-body absorbed dose of 500 rads. The rats were irradiated in a lucite wheel (*11*) radially divided into 16 individual compartments, and were rotated under the x-ray beam at a rate of 3 rev/min. The source of radiation was a medical x-ray therapy machine operated at 250 kv (peak), 15 ma, 159 cm source to skin distance, with an added filtration of 0.5 mm Cu + 1 mm Al (half-value layer: 1.38 mm Cu). The resultant dose rate was 8.83 rad/min. Immediately after exposure and daily thereafter, the rats were injected subcutaneously with either 0.1 ml of saline solution containing 2 units of NPH insulin or with saline solution alone. Another group of rats served as controls and were injected with insulin, but were not x-irradiated. Daily urine specimens were collected for 3 days before and for 3 days after exposure of the rats to x-rays. Urinary creatine was determined essentially by Kibrick's modification (*12*) of the coupled enzyme method described by Tanzer *et al.* (*13*).

The results are shown on Table 1.