press) and also, by individual analysts, in (*3*) and (*4*) above. The samples used are: PSU sample L-12 = LN45, Bikita Quarry, Southern Rhodesia; L-13 = L-A106, Bob Ingersoll Mine, South Dakota; L-14 = L-A110, Varutrask Quarry, Sweden; and L-15 = L-A107, Pala Mine, San Diego County, Calif.

8. This work was supported by the Mineral Conservation section of Pennsylvania State University. I wish to thank Dr. Egon T. Degens, Mr. Dieterich Welte, Mr. Werner Deuser, and Mr. Robert Shutt for instruction and assistance. Samples were graciously provided by Prof. Harrison Brown of California Institute of Technology (the M.I.T. supply being exhausted). This report is contribution No. 60-2, College of Mineral Industries, Pennsylvania State University.

9 November 1959

Rates of Submergence of Coastal New England and Acadia

Abstract. Altitudinal and carbon-14 age determinations of in-place *Pinus strobus* stumps of drowned forests at Odiorne Point, N.H., and Grand Pré and Fort Lawrence, Nova Scotia, yield apparent average rates of submergence of 3.1, 14.5, and 20.3 feet per 1000 C^{14} years, respectively. Rate differences are assessed in terms of eustatic rise of sea level, crustal movements, and tidal effects.

Radiocarbon dates for drowned trees along the New England coast have been reported by several investigators (*1–4*), but these determinations only fix the general period of submergence of the coastline. On the basis of earlier work on drowned forests (*5*), one of us (C.J.L.) was able to plan the present study, which provides a measure of the rate of coastal submergence at each of three drowned-forest sites. The initial assumptions of this study were that rising salt water killed the trees from which wood could be dated by C^{14}, that submergence of the forests was progressive at each site, and that the approximate average rates of submergence could be determined from a knowledge of the dates of death of trees at sufficiently different altitudes at each locality.

The drowned forest at Odiorne Point, N.H., near lat. 43°2′ N., long. 70°44′ W., consists of the remains of a coniferous stand whose stumps and fallen trunks are found within a protected cove measuring about 500 feet in diameter. The stumps are rooted in a firm woodland peat, ranging from 2 to 4 feet in thickness, that overlies till and bedrock.

The famous drowned forest at Fort Lawrence, N.S., near lat. 45°50′ N., long. 64°17′ W., has now lost most of its exposed soil and the stumps rooted in it. The site can be reached by following Dawson's directions (*6*). Samples of the forest soil, described by Dawson as "black vegetable mould, resting on a white, sandy subsoil" (*6*, p. 441), proved to be clay loam colored with forest humus to a depth of 6 inches. The "white" layer is underlain by 8 to 9 inches of red sandy loam, which in turn rests on till.

At Grand Pré, N.S., the remains of a forest extend over at least 100 acres of mud flats exposed at low tide on the north side of Boot Island (lat. 45°8′ N., long. 64°17′ W.), near the south shore of the Minas Basin. Stumps are rooted in 15 to 18 inches of gray clay soil that rests upon a pale-red clay layer varying in thickness from 12 to 24 inches, underlain by stony till.

Samples for C^{14} dating were cut from stumps of four white pine (*Pinus strobus*) trees at each of the three sites. The altitudes of the bases of the stumps were determined by standard leveling techniques. Stump altitudes were related to mean sea level, as determined from tide-table data and the observed high-tide mark for the date of the field work at each site. The precise altitudes, relative to mean sea level, of the dated stumps are not critical to the determinations of rates of submergence; only the relative differences in altitudes between stumps at each site are critical. These last altitude values are believed accurate to ± 0.4 foot.

The wood used for C^{14}-age determinations reported in the present paper was taken from the outer rings of the highest and lowest stumps at each site. It was free from contamination by borers and other organisms. Stump-base altitudes and C^{14} ages are shown in Fig. 1. The following speculations about the data are offered.

1) If the rates of coastal submergence were constant at each of the three sites between 4450 and 3200 years before the present (B.P.), the average rate of submergence at Odiorne Point corresponds closely to the approximate average rate of postglacial rise of sea level (Fig. 1), as determined from data presented by Shepard and Suess (*7*, Fig. 1). Crustal stability at Odiorne Point during this time interval would thus be implied, but later upwarping would be required, because the stumps are some 12 feet closer to present sea level than the materials that were dated in Shepard and Suess's study (Fig. 1). Also, the apparent average rate of submergence in the Fort Lawrence–Grand Pré area would amount to roughly three times that which would have been induced by the rate of postglacial rise of sea level determined from Shepard and Suess's data. The greater rate of submergence could probably best be explained as resulting from slow crustal downwarping in the Nova Scotian region, simultaneous with sea-level rise. The possibility that the Nova Scotian submergence rate reflects wholesale tree death during part of the time interval, and is attributable to the breaking of barriers between ocean and forests or to a rapid displacement of the crust, is improbable (*5*, p. 614). Relatively long periods of time were involved in the killing of successively higher trees by the rising salt water (*5*). Another consideration is that greater submergence rate might in some way be related to a progressive increase in tidal range, as continued submergence brought ocean waters farther and farther into the Fundy embayment (*8*, p. 580).

2) If submergence at each site coincided with eustatic oscillations of sea level of the type suggested by Fair-

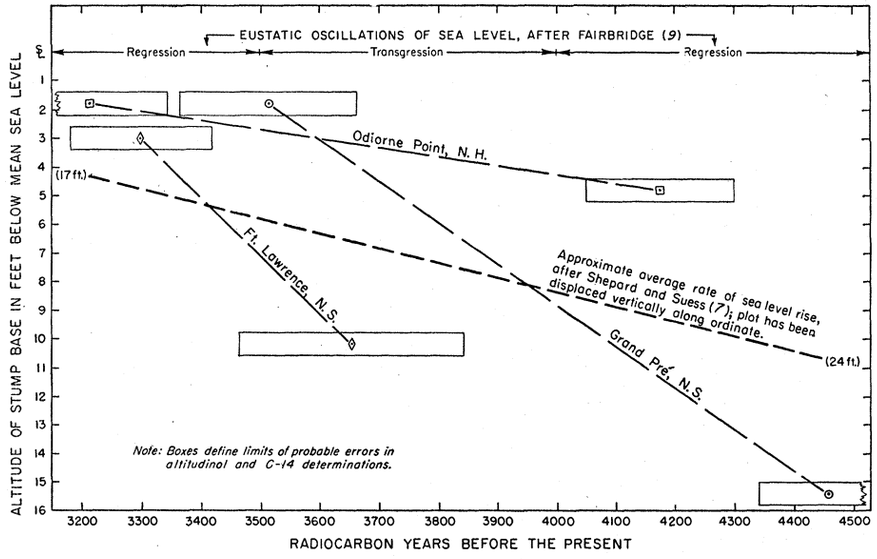

Fig. 1. Altitude versus age for two *P. strobus* stumps at each of three drowned-forest sites, and apparent average rates of site submergence.

bridge (*9*, Fig. 1), the submergence sequences may be considerably more complicated than our Fig. 1 indicates. Because three of our trees were killed by rising salt water during two of Fairbridge's postulated regressions of sea level [see also Hussey (*4*, Table 1), 3250 ± 200 B.P.], their deaths would have to be explained by crustal downwarping at rates in excess of the eustatic regressions.

We wish to withhold judgment on these speculations, pending C^{14} dating of six samples from stumps at intermediate altitudes at each of the three sites (*10*).

C. J. LYON
Dartmouth College, Hanover, New Hampshire
W. HARRISON
College of William and Mary at Norfolk, Norfolk, Virginia

References and Notes

1. W. H. Bradley, *Am. J. Sci.* **251**, 543 (1953).
2. W. F. Libby, *Radiocarbon Dating* (Univ. Chicago Press, Chicago, Ill., 1955).
3. E. S. Deevey *et al.*, *Am. J. Sci., Radiocarbon Suppl.* 1, 145 (1959).
4. A. M. Hussey II, *J. Sediment. Petrol.* **29**, 465 (1959).
5. C. J. Lyon and J. W. Goldthwait, *Geograph. Rev.* **24**, 605 (1934).
6. J. W. Dawson, *Am. J. Sci.* **21**, 440 (1856).
7. F. P. Shepard and H. E. Suess, *Science* **123**, 1082 (1956).
8. D. Johnson, *The New England-Acadian Shoreline* (Wiley, New York, 1925).
9. R. W. Fairbridge, *Trans. N.Y. Acad. Sci.* **20**, 471 (1958).
10. This study was supported by a grant to one of us (C.J.L.) from the National Science Foundation. Carbon-14 dating was done by Isotopes, Inc., Westwood, N.J.

15 April 1960

Antithyroid Effects of Aminotriazole

Abstract. Aminotriazole, like other antithyroid compounds and low-iodine diets, produces adenomatous changes in the thyroid glands of rats when fed continuously for long periods. Such changes are reversible if the antithyroid regime is discontinued. The antithyroid compounds that are naturally present in food are not regarded as causes of cancer.

The action of the Food and Drug Administration in seizing shipments of cranberries containing alleged residues of the herbicide aminotriazole (3-amino-1,2,4-triazole) (*1*) makes it desirable to summarize briefly some unpublished findings with this substance (*2*, *3*).

A large number of compounds have the property of inhibiting the thyroid gland from reacting with inorganic iodide to form the thyroid hormone (*4*). Prominent among these "antithyroid" compounds are certain substances containing the –NH–CS– grouping, including thiouracil, and a number of aminoheterocyclic compounds, including aminotriazole (*5*). Many foods, including cabbage, turnips, peas, beans, strawberries, and milk, contain antithyroid substances (*6*), one of which, L-5-vinyl-2-thiooxazolidone ("goitrin"), has been isolated in quantities as high as 200 parts per million from rutabagas and has a potency equal to that of thiouracil as measured in human subjects (*7*).

In experiments in our laboratories (*3*) enlargement of the thyroid gland in rats and pronounced lowering of uptake of administered radioiodine by this gland were produced by feeding diets containing 60 or 120 parts per million of aminotriazole for 2 weeks. There were no significant changes in the gland at levels of 15 and 30 parts per million.

In studies carried out at a consulting laboratory (*8*), rats were fed diets containing 0 (group 1), 10 (group 2), 50 (group 3), and 100 parts per million (group 4) of aminotriazole. After 24 months the animals were sacrificed and a histological examination was made of some of the thyroid glands. No tumors were found in five thyroid glands examined in group 1, although there was one cystic follicle with papillary change that is typically the forerunner of a very large cystic adenoma. One adenoma was found in ten thyroid glands in group 2. Two of the 15 glands in group 3 and 17 of the 26 glands in group 4 were found to be adenomatous. One gland in group 3 and four in group 4 showed changes which were interpreted by some pathologists to be adenocarcinomatous and by others to be nonmalignant. The exact significance of these changes in relation to spontaneous thyroid pathology in rats of this age needs extended discussion beyond the scope of this brief article and will be reported elsewhere (*2*). After 17 weeks, aminotriazole was withdrawn from the diet of a fifth group of rats that had received 500 parts per million, and 2 weeks later their thyroid glands were found to be normal in appearance.

It has long been recognized that suppression of the function of the thyroid gland in rats by administration of antithyroid compounds or by deprivation of dietary iodine leads to an increase in the production of the thyroid-stimulating hormone of the pituitary and a consequent increase in the size of the thyroid gland (*9*). The prolongation of either type of regimen led to the emergence of thyroid adenomata (*9*, *10*, *11*) which were not seen when the feeding of the antithyroid diet was alternated with periods of control diet (*10*).

By continuing the feeding of comparatively high levels of such antithyroid substances as thiourea and thiouracil to mice, lung nodules of thyroid-like tissue were eventually produced (*12*). Adenocarcinomatous tumors were produced in rats by prolonged treatment with thiourea. No metastases were found and the authors regarded this absence as evidence against any direct carcinogenic effect of thiourea, but rather as reflecting the overproduction of a normal body constituent, thyroid-stimulating hormone (*13*).

These and other observations make it apparent that an antithyroid regimen in experimental rats and mice can be predicted to result eventually in the appearance of thyroid tumors. Some of these may reach a stage that is regarded by some authorities as adenocarcinomatous, although this point is debated by other investigators who consider the changes as resembling benign tumors (*14*). In any case, such a stage has been described only if the treatment corresponded to complete blocking of the thyroid gland taking place continuously for most of the normal lifetime of the animal. Moderate or intermittent treatments with antithyroid substances have not been reported to lead to the production of tumors. Indeed, the consumption of foods that inherently contain antithyroid substances is not usually regarded as a potential cause of cancer in human beings. Furthermore, thiouracil and its congeners are commonly used clinically in the treatment of hyperthyroidism, thus giving additional clinical experience in the use of compounds of this type (*15*).

Recently Hoshino has reported in a preliminary communication that injections of aminotriazole significantly delayed the production of liver cancer in rats that received the carcinogenic dye, 4-dimethylaminoazobenzene (*16*). This recalls the finding by Paschkis and coworkers (*17*) that another antithyroid compound, thiouracil, protected the livers of rats against the carcinogenic action of 2-acetaminofluorene.

The characterization of the antithyroid compound aminotriazole as a cancer-producing substance would seem to be questionable and in any case needs careful definition of conditions. Foods containing antithyroid substances are universally present in ordinary diets.

T. H. JUKES
C. B. SHAFFER
American Cyanamid Company, New York 20, New York

References and Notes

1. G. DuShane, *Science* **130**, 1447 (1959).
2. C. B. Shaffer *et al.*, unpublished observations.
3. R. G. Eggert, unpublished observations.
4. G. W. Anderson, *Medicinal Chem.* **1**, 1 (1951).
5. N. M. Alexander, *J. Biol. Chem.* **234**, 148 (1959).