19 days of growth) was conducted, using the flour diet (Table 1) and increasing supplements of *Chlorella* to obtain some estimate of effective amounts. *Chlorella* at levels of 1, 2, 4, and 6 percent produced growth 1.3, 2.1, 2.3, and 3.8 times greater than that of animals receiving no *Chlorella*. An additional group in this series received the flour diet plus lysine and threonine and attained a weight 5.5 times greater than the groups that received no algae or amino acid. This suggests that *Chlorella* at the 6-percent level did not fully provide the lysine and threonine that was required under these conditions. A limited supply prevented the testing of higher concentrations of *Chlorella*. A similar experiment, in which all the flour diets were supplemented with lysine, also showed increasing growth with increasing levels of *Chlorella*. However the diets with 4- and 6-percent levels of *Chlorella* produced almost the same growth, the difference not being significant statistically. This result suggests that 4-percent *Chlorella* supplied about as much threonine as the rat could use under these conditions (with lysine added).

Lysine can be produced synthetically at modest cost. A lysine-enriched bread is being marketed experimentally. Threonine, however, remains very expensive. Therefore, additional experiments were conducted to evaluate *Chlorella* as a source of threonine in supplementing enriched white bread, and to compare algae with other sources of protein in this respect. These diets were supplemented with vitamins, minerals, fat, and lysine (except for one control group) to remove possible limitations on growth other than threonine. The first four groups in Table 2 indicate that *Chlorella* is an effective source of threonine in supplementing enriched bread, as judged by both growth and food efficiency. The experiment represented by the last seven groups was conducted at a different time than that represented by the preceding groups. The results are comparable, however, as indicated by the similar growth of the group in each series (96 and 94 g) that received a lysine supplement. The results indicate that *Chlorella* is a better source of threonine than purified soya protein and is equal to several animal-protein foods of high biological value when used as food supplements isonitrogenous to *Chlorella*.

These data indicate that algae protein may have considerable potential application as a source of amino acids that are generally low in cereals.

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Table 1. Effect of *Scenedesmus obliquus*, lysine, and threonine in white flour or bread diets. Each group consisted of 9 or 10 National Institutes of Health black male rats. Each rat was housed separately in a raised-bottom, wire-mesh cage. Diets were fed *ad libitum*. The flour diet consisted of commercial unenriched white wheat flour (92 g), starch (1 g), cottonseed oil (3 g), and HMW salts (4 g) (*12*). Each gram of starch contained added thiamine (0.2 mg), riboflavin (0.3 mg), pyridoxine (0.25 mg), pantothenate (2 mg), niacin (2 mg), folic acid (0.1 mg), biotin (0.01 mg), 2-methyl naphthoquinone (0.1 mg), inositol (10 mg), and choline chloride (100 mg). The 3 g of cottonseed oil contained added vitamins A and D (550 and 110 U.S.P. units, respectively) and α-tocopherol (5 mg). The bread diet consisted of commercial white enriched bread (3 percent dry skim milk solids) that was air dried and ground to a powder. No other vitamins, minerals, or fat were added.

Group	Diet	Weight gain in 27 days (g/rat)*
1	Flour	6.4 ± 0.6
2	Flour with 4% *Scenedesmus*†	20.3 ± 1.2
3	Flour with 0.75% lysine · HCl	25.0 ± 1.2
4	Flour with 0.75% lysine and 4% *Scenedesmus*†	53.2 ± 3.1
5	Flour with 1.2% DL-threonine	7.3 ± 1.0
6	Flour with 1.2% DL-threonine and 4% *Scenedesmus*†	18.6 ± 1.8
7	Flour with 1.2% DL-threonine and 0. 75% lysine · HCl	46.5 ± 2.9
8	Bread	22.0 ± 1.2
9	Bread with 4% *Scenedesmus*†	40.8 ± 2.6

* Standard error = range divided by number of animals (*13*).
† The algae replaced an equal weight of flour or bread.

Table 2. *Chlorella pyrenoidosa*, lysine, threonine, and various proteins as supplements in enriched white-bread diets. The rats tested were Osborne-Mendel male weanling rats. Each group contained ten rats, except the group that received *Chlorella*, which contained 5 rats. The bread diet contained air-dried commercial white enriched bread (3 percent dry milk solids) (92 g), HMW salts (4 g) (*12*), starch (1 g), and cottonseed oil (3 g). The starch and cottonseed oil provided vitamins in the same amounts as those listed in Table 1. The amino-acid and protein supplements replaced an equal weight of bread in the diets.

Diet	Weight gain in 28 days (g/rat)	Food efficiency*
Bread	14.8 ± 1.6	11.7
Bread with 0.75% lysine · HCl	96.3 ± 10.0	3.2
Bread with 0.75% lysine · HCl and 4% *Chlorella*	133.0 ± 8.4	2.9
Bread with 0.75% lysine · HCl and 1.2% DL-threonine	139.3 ± 5.7	2.6
Bread with 0.75% lysine · HCl	94.0 ± 1.7	3.6
Bread with 0.75% lysine · HCl and 2.1% casein	116.1 ± 4.0	3.1
Bread with 0.75% lysine · HCl and 2.1% soya protein	99.1 ± 5.9	3.5
Bread with 0.75% lysine · HCl and 2.9% dried liver	117.6 ± 4.3	3.2
Bread with 0.75% lysine · HCl and 5.4% dry skim milk	127.3 ± 3.8	3.0
Bread with 0.75% lysine · HCl and 4.9% whole dried egg	123.2 ± 8.4	2.9
Bread with 0.75% lysine · HCl and 1.2% DL-threonine	125.4 ± 4.2	3.0

* Food efficiency = grams of food eaten per gram of weight gained.

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19 July 1956

San Augustin Plains—Pleistocene Climatic Changes

The sediments of the former Lake San Augustin, Catron County, western New Mexico, afford a long and apparently continuous record of vegetation and climate (*1*). These deposits form the San Augustin Plains below the well-known Bat Cave, within a closed basin some 7000 feet above sea level and in a region of definite though irregular altitudinal belts of vegetation. The flora of this basin is now alkaline semidesert, with chenopods (*Atriplex* and *Sarcoba-*

tus) in the alkaline or heavily grazed areas and considerable short-grass (*Sporobolus*) on the flats and *Bouteleoa* on the surrounding uplands.

Above this grassland, as elsewhere in New Mexico, is the woodland zone of juniper (*Juniperus* ssp.) and piñon (*Pinus edulis*) whose nearest outliers reach the basin rim. The ponderosa pine (*Pinus ponderosa*) zone is still higher and farther away, except where it descends locally in occasional canyons or on sandy soil. On the highest elevations and in protected sites of the ponderosa pine belt may be found limber pine (*Pinus flexilis*), Douglas fir (*Pseudotsuga taxifolia*), and white fir (*Abies concolor*). Spruce (*Picea* ssp.), so far as is known, is confined to high elevations beyond the present limits of the basin drainage.

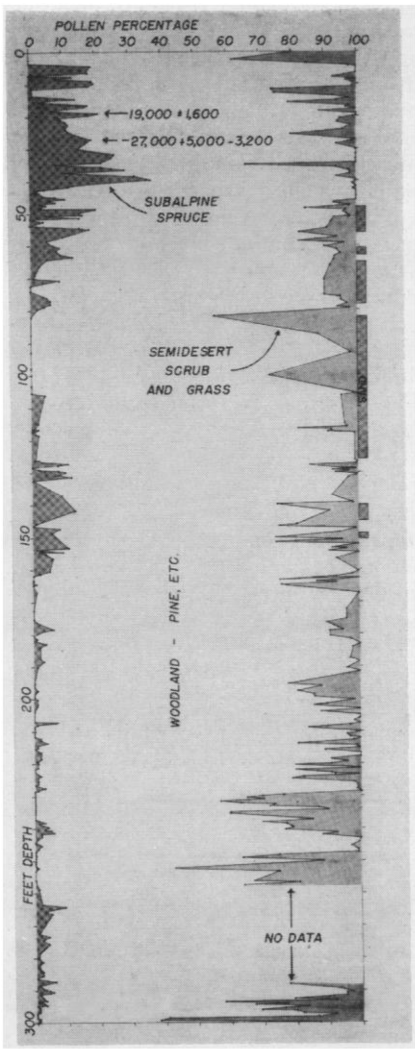

Fig. 1. Pollen profile from the San Augustin Plains, New Mexico. Percentages of nontree pollen, chiefly chenopods, composites, and grasses, are shown at the right of the diagram, and spruce at the left. The middle strip represents background, chiefly pine with some oak. Occasional sharp, temporary increases of aspen and juniper at the expense of pine, owing to drouth, fire, or other edaphic causes, are included as background but are not shown. Spruce "curve" is an approximate thermograph if it is read from right, falling where spruce is abundant (low temperature) and rising at spruce minima (high temperature). The nontree graph although incomplete, is an approximate measure of aridity. The depth scale is a function of time and rate of sedimentation. It is uncalibrated except where dates are shown.

Although this general pattern of zonation is subject to considerable local variation because of slope, soil, and exposure, any consistent shift in altitudes as indicated by the pollen profile should be evidence of temperature change. Specifically, any increase in spruce-fir pollen in basin deposits would indicate low temperature. In addition, the presence of lacustrine algae (not shown in Fig. 1) serves to indicate periods of moisture sufficient to maintain a lake in the basin. In times of greater aridity such lakes would become more saline and gradually dry up, with an increase in the semidesert vegetation.

Fir and Douglas-fir pollen are rare, presumably owing to limited distance of transport, while juniper, aspen, and oak appear only at intervals. Pine serves chiefly as background, because of its great altitudinal range and the difficulty of specific identification of piñon and ponderosa-pine pollen.

Figure 1 represents the pollen profile of the upper 300 ft of a 645-ft core, analyzed at close intervals (1 ft or less). An additional 120 ft, analyzed at 3-ft intervals, is not shown but is discussed in later paragraphs. Spruce (subalpine) percentages are shown in the shaded area at the left, nontree (semidesert) scrub and grass) in the shaded area at the right; the unshaded space between represents background, essentially pine but including a few other tree genera. On the assumption that the amount of spruce varies inversely with temperature, its graph, read horizontally, may be taken to represent the rise and fall of temperature. The crest of the nontree pollen graph, on the other hand, may be regarded as an essential measure of aridity.

The present vegetation of the basin is clearly reflected in the total absence of spruce pollen and in the abundance of chenopod pollen against a background of pine at surface level, 0 ft. From about 5 to about 70 ft, the abundance of spruce indicates a prolonged period of low temperature, with marked interruptions at about 12 and 52 ft.

There is another definite and prolonged interruption extending from about 70 to about 125 ft. Below this, at approximately 125 to 155 ft, there is another cold period, likewise showing interruptions. From 155 ft to the aforementioned 300-ft depth, spruce never reaches high proportions, although it shows slight but definite peaks at intervals. Preliminary analysis of the further 150 ft mentioned in a preceding paragraph gives no evidence of additional cold, high-spruce episodes down to 450 ft.

From 230 to 450 ft the nontree pollen contained significant amounts of sagebrush (*Artemisia*), but above 230 ft mainly chenopods (*2*).

On the assumption that low temperatures in this area accompanied glaciation, a group of glacial episodes appears to be represented in the upper spruce segment of the profile (approximately 5 to 70 ft). A carbon-14 date of 19,700 ± 1600 years at the 19-ft level has been determined (*3*), and a less reliable one (now being rerun owing to background difficulties) of 27,000 + 5,000 years or − 3200 years at the 28-ft level.

The upper series of glacial episodes appears to be separated from an earlier series (approximately 125 to 155 ft) by a nonglacial interval, while conditions below 155 ft appear to have been nonglacial to the depth of at least 450 ft.

As proper checks on this study, the vegetation and present-day pollen deposits of the San Augustin area are being investigated by Loren Potter and the sedimentary history is being investigated by Fred Foreman, who has supplied information on the sand layers shown in the graph. Since this sand may have accumulated rapidly, the interval between the two series of glacial episodes is of uncertain length. A further complication in this important segment (80 to 120 ft) is that there are considerable intervals between reliable counts, owing to pollen scarcity. There is no reason to doubt the consistent low percentage of spruce, but the graph of nontree pollen is highly generalized in this interval.

Laborious and exacting as this type of work proves to be, the results thus far obtained suggest that it should be continued by coring to the base of the sediments and that it should be extended to a number of the other lacustrine deposits in the Southwest. In this way a complete sequence for the Pleistocene and, perhaps by sufficient attention to details of nonglacial times, a better understanding of the fundamental characteristics of climate could be established (*4*).

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References and Notes

1. See the accompanying papers by C. E. Stearns and by F. Foreman in this issue.
2. Discussion of this and other interesting details must await later presentation.
3. This was accomplished through the courtesy of the Magnolia Petroleum Company.
4. Grateful acknowledgment is due to the division of earth sciences, National Science Foundation,

for its support of this project. Potter's work is being sustained by a grant from the division of environmental studies of the NSF, and to him we are indebted for advice on this paper. To Johs. Iversen special thanks are rendered for his wise and generous counsel.

1 June 1956

San Augustin Plains—the Geologic Setting

The San Augustin Plains occupy a high, intermontane basin on the continental divide in the Datil-Mogollon volcanic plateau of western New Mexico (*1*). Their general features have been described by Bryan (*2*) and Powers (*3*). At present, a playa occupies approximately 35 mi^2 at the west end of the plains. During the late Pleistocene at least, a maximum area of 255 mi^2 was occupied by pluvial Lake San Augustin. Postlacustrine erosion and sedimentation have produced only local and minor modifications of the features of the lake.

The highland areas bordering the basin are chiefly erosional remnants, carved in Tertiary volcanic rocks. Typical sections have been described by Powers (*4*), and I am currently engaged in more detailed studies of the sections in the northern half of the Pelona quadrangle for the New Mexico Bureau of Mines and Mineral Resources. Rock types range from rhyolite to basalt, and both flow and pyroclastic units are represented. Fluviatile and eolian beds are locally important. Thus, during most of the history of sedimentation in the basin, tributary streams have had continual access to a variety of types of volcanic rock. Significant variations in mineralogy of the basin sediments must be ascribed to variations in the surficial processes of erosion and deposition rather than to differences in the original character of source rocks exposed at various times.

The dissected flanks of two principal highlands on the south margin of the plains, O-Bar-O and Pelona Mountains, simulate the forms of broad lava cones. The basaltic lavas in these cones constitute the youngest volcanic unit that has been recognized in the north half of the Pelona quadrangle. They are probably as young as the Pliocene or Pleistocene.

The San Augustin Plains have the general form of a graben, although conclusive evidence of its origin has not been forthcoming. However, in several marginal areas, minor faults parallel linear segments of the topographic margins of the basin. These faults would be appropriate secondary members of fault zones, the principal displacements in which form structural boundaries to the basin. Near Bat Cave, late basalt flows peripheral to Pelona Mountain are broken by such faults. Thus, the San Augustin Plains appear to be a graben, the principal development of which postdates Pliocene or younger volcanics. No evidence was found of local volcanic activity contemporaneous to sedimentation in the graben.

The thickness of the unconsolidated sediments underlying the plains is known, from water wells, to exceed 1200 ft. If the graben is chiefly post-Pliocene (?), one would expect, as a first approximation, that the 645-ft core taken for detailed study would record, at most, the latter part of the Pleistocene. However, this approximation is extremely crude, and more precise inference of age must be sought in the core itself.

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References and Notes

1. See the accompanying papers by K. H. Clisby and P. B. Sears and by F. Foreman in this issue.
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21 June 1956

San Augustin Plains—the Sediments

The sediments from an almost continuous 645-ft core from the extinct Lake San Augustin are being studied (*1*). This old lake floor, elevation 6775 ft. is situated in the southwestern part of the San Augustin Plains of New Mexico. The drill site is near the center of the present playa, some 4 mi from the nearest slopes of the surrounding hills. It is believed that the sedimentation in this part of the lake was least affected by fluctuations of lake level or by deposits from any one stream and that, therefore, this core gives as good a picture of the general lake sedimentation throughout its length as could be attained with a linear series of samples.

Textural analyses, petrographic studies, and carbon dioxide determinations are being carried out, and, in the clay-sized particles, some *d. t. a.,* x-ray, and spectographic analyses have also been made.

The work to date shows that, if authigenic minerals are disregarded, the sediments are nearly all clayey silts, except for the interval between 45 ft and 215 ft, where there are alternating layers of sand and clayey silts. However, from 80 ft to 125 ft in this zone, the sand is almost continuous.

Carbonates, calcite, and dolomite are authigenic and are found in all samples of the core; the CO_2 ranges from 0.3 to 26.4 percent but is generally between 2 and 6 percent. These carbonates occur in all grade sizes, sometimes as single crystals, sometimes as aggregates, and they vary in color from clear to white to buff. The allogenic minerals are evidently those of the igneous rocks surrounding the basin; feldspar, hornblende, pyroxene, mica, olivine, and quartz are commonly found, and, except for the mica, these are generally fresh and angular. In some instances, rock particles, usually subangular to round, occur. These are usually of andesitic rock but range from rhyolite to basalt. The clay-size fraction consists of clay minerals (montomorillonite, nontronite, and allophane) and carbonate (calcite and dolomite) with small amounts of allogenic minerals, chiefly quartz and feldspar.

The only fossils found in these sediments are pollen, algae, ostracods, and rare opaline particles that may be diatoms. The sedimentation in this lake was probably slow, except for the sand horizons between 45 and 215 ft. This sand is widespread, as is shown by the wells in the lake floor, nearly all of which find their water between the 60- and 200-ft levels.

It would seem, then, that conditions of erosion and deposition were fairly constant, except when these sand layers were deposited, and their origin appears to be the result of more rapid erosion by the streams entering the basin.

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Reference

1. See the accompanying papers by K. H. Clisby and P. B. Sears and by C. E. Stearns in this issue.

13 July 1956

When our conceptions are clear and distinct, when our facts are certain and sufficiently numerous, and when the conceptions, being suited to the nature of the facts, are applied to them so as to produce an exact and universal accordance, we attain knowledge of a precise and comprehensive kind, which we may term Science.—WILLIAM WHEWELL, *The Philosophy of the Inductive Sciences* (1847).