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SELENOLOGY AND COSMOGEOLOGY

COSMIC AND GEOLOGIC IMPORT OF THE LUNAR FEATURES

By Dr. HERMAN L. FAIRCHILD

EMERITUS PROFESSOR OF GEOLOGY, UNIVERSITY OF ROCHESTER

APOLOGY: In slight excuse for trespassing in the astronomic field it may be said that a geologist, cooperating with an astronomer, showed the fallacy of the nebular hypothesis, which had been cherished by astronomers and selenographers for more than a century; and that a student in geology may have some reasonable ideas in selenology.

Thesis: The basins and pittings of the lunar surface are impact craters and are ocular confirmation of the view that the planets and satellites were built by cold accretion. This implies acceptance of the planetesimal hypothesis of Chamberlin and Moulton. The genesis, growth, history and structure of the earth and moon are here considered from the planetesimal view-point.

Ever since Galileo first peeked at the moon through his crude telescope, the lunar surface has been perhaps the most singular, fascinating and puzzling of telescopic objects. Galileo's surprise and delight have been reexperienced by all observers, and for four centuries selenography has been a favorite pastime for sky-gazers. Description and portrayal of the so-called craters and of the plains, mountains and the many peculiar features make an extensive literature. In recent time photography has largely displaced pen and pencil. Naturally the moon has been the subject of much speculation and imaginings and the cause of superstition and mental aberration. Scientific literature includes much lunar description that is unscientific and even unreasonable. The most pretentious treatise on the moon in American literature argues for the existence on the moon of atmosphere, snow, ice and vegetation. This ignores the heated condition of the surface during the long lunar day. It would be a new

sort of vegetation that could endure the great extremes of temperature between the lunar day and night. With all this interest in and study of the moon, the origin of its striking features yet remains in question.

LUNAR CRATERS

The most important error in the lunar study relates to the so-called craters. Until later years the tens of thousands of pittings and circular depressions have been quite universally regarded as of explosive or volcanic origin. The volcanic conception was naturally involved in the erroneous nebular hypothesis to be described below. Volcanism seemed to be the natural or even inevitable stage in the cooling of a molten globe. However, with the exception of the circular form of the basins and the supposed resemblance of the lunar substance to volcanic scoria, it is questioned if there is a single feature of the moon's surface that simulates or illustrates volcanism as we find this upon the earth. A casual resemblance of the lunar features to terrestrial volcanic craters was accepted as proof of volcanism, and the negative facts and philosophy were neglected. The evidence and argument in negation of lunar volcanism and the rational substitute will be considered later in this writing. The study of the moon, selenology, has been retarded by adherence to a mistaken conception of planetary genesis. The same is emphatically true of geology, which held the belief that the earth was originally a molten, incandescent sphere. Most serious problems in geology refer, in their final analysis, to the manner of formation of the earth. It is desirable now to review briefly the astronomic element in our earth science.

NEBULAR, LAPLACIAN, HYPOTHESIS

This hypothesis postulated that the material of the solar system was originally a discoid or wheel-shaped nebula of superheated gas with rapid revolution. By centrifugal force successive rings were detached, which in some manner evolved the planets; the sun being the undistributed central mass. This hypothesis required that all the planets, planetoids and satellites should pass from a superheated gaseous condition through a molten state. This conception, which involved a molten incandescent earth, was universally accepted for a hundred years down to the close of the last century. Yet the conception was not true. It remained for a geologist with the collaboration of an astronomer to prove its fallacy. They found that the Laplacian conception failed at every point where it was tested by modern physics.

PLANETESIMAL HYPOTHESIS

As a substitute for the mistaken hypothesis Professor T. C. Chamberlin with Professor F. R. Moulton formulated in the year 1900 the planetesimal hypothesis. This new conception holds that the materials which constitute the planets, planetoids and satellites were derived from the sun through gravitational effect by a passing star. The combination of forces and movements involved in the dynamic encounter threw the expelled and disseminated solar material into orbital revolution around the parent body.

Under this hypothesis the planets and satellites, including of course the earth and moon, were formed by a process of cold accretion. They were built up from nuclei by ingathering through overtake and intake of solar material, bodies large and small, the "planetesimals" all traveling in the same general direction in various orbits about the sun.

OTHER COSMIC HYPOTHESES

The astronomers and astrophysicists finally accepted the death sentence on the Laplacian conception; and some of them soon formulated their own hypotheses as rivals or substitutes for the planetesimal. During the last thirty-five years the considerable literature on the subject records many changes and revisions in the hypotheses. Like the planetesimal, these conceptions are all based on assumptions.

In his recent book, "The Solar System and Its Origin," Professor H. N. Russell has briefly reviewed the several hypotheses of the genesis of the solar system and concludes with these words, "The most encouraging direction for this attempt would still appear to be in the modification of the hypothesis of an encounter." We may claim that the planetesimal hypothesis yet stands with the simplest assumption and the most reasonable sequence of process and events.

Our planetary system had a biparental origin. The father star passed on his way with calm indifference, leaving to the mother sun the responsibility of training her brood and bringing it into the present orderly and stable system, the solar family, as Chamberlin aptly called it.

ORIGIN OF THE EARTH

The astronomic philosophy covering the origin of the planetary system has relation to fundamental geologic philosophy.

The conception of an originally molten earth was inherent in and necessitated by the nebular hypothesis, and down to forty years ago our earth science was based on the conception of an originally molten globe. With the passing of the nebular hypothesis the molten-globe idea should have been discarded as having no factual basis. Yet the idea was so imbedded in scientific thought and literature that it survives and yet appears in scientific writings.

The question might be asked: Could not the earth have been originally molten under some conception of

the origin of the planetary system other than the nebular hypothesis? Under any conception of planetary origin thus far proposed the answer is fairly negative. It is now generally recognized that the planetary system is composed of materials derived from the sun and that its present form is the product of an organizing process acting through vast eons of time. Concerning the origin of the earth only two conditions seem possible. Either it was born with full volume and mass or else it grew by some manner of accretion. Whatever was its origin and history the same must be attributed to all the other planets. The earth could not have been unique.

If the earth, derived from the solar atmosphere, held at once as a gaseous globe all the substance of the present earth, then a similar condition was true of all the planets. Such initial concentration of nearly all the substance of the planetary system is not only highly improbable, but it would be quite impossible to trace its evolution into the dynamics and structure of the existing system.

If the earth was built by accretion and yet was molten when completed, then the ingathered materials had retained their solar heat during all the vast lapse of time necessary for the accretionary process. This seems impossible. The solar substance drawn from, or expelled from the sun was thrown far out into interstellar space. (Pluto is over three and one-half billion miles from the sun.) This gaseous material was subjected to the absolute zero temperature in the vacuum of space. It must promptly have been condensed to fluid and eventually to the solid state. Astronomic science does not truly favor in fact or philosophy the conception of a molten earth.

Discussion of the genesis of the solar system during the past thirty-seven years has left the Chamberlin-Moulton planetesimal hypothesis as the one with the least assumption and the most reasonable, simple and satisfactory conception yet proposed, and the one most in harmony with geologic facts. Geology favors the cold accretion theory.

Absence of Lunar Volcanism

The many singular features of the lunar surface were attributed to volcanism in the absence of any other scientific explanation, and the physical characters in negation of volcanism were not properly considered. One of the latter relates to the moon's structure.

The earth and the moon, built of planetesimals, have similar composition. The only materials on the earth with which the moon's substance may be compared, and only by ocular and spectroscopic means, are the volcanic scoria and lavas, which do have superficial resemblance. The exterior mass of the earth, to a depth of quite two thousand miles, has been subjected to the alterative work of water and air, producing materials and structures entirely absent on the moon. The lunar substance is the unoxidized, unhydrated, unaltered planetesimal stuff. The name "lunite" will now be used.

The earth's exterior mass is compact, solid rock. Through fissures in the crust and by outflow of molten magma some large part of the earth's imprisoned gases, the magmatic volatiles, found slow and quiet escape. Some part escaped imprisonment by violence, producing volcanoes. On the earth's entire surface volcanism is a rare and widely scattered feature. Unlike the earth the moon has no compact rock strata. Being gravitationally incompetent to hold gases on its surface, it never had an atmosphere and ocean. Whatever was the genesis of the moon, its surface material has never been compacted by water action, sedimentation.

The moon's substance has been generally described as scoria. Temperature measurements indicate that the material is highly porous. It thus appears that the surface material is relatively incoherent. Its nature is evidently what would be expected from accumulation through planetesimal accretion. Undoubtedly the moon inherited in its solar substance its proper share of volatile elements, and these volatiles must have found easy escape. The magmatic vapors of the lunar body were able to escape with relative ease through the uncompacted surficial mass, and no cause or condition is found for explosive phenomena.

Meteor Crater

The only feature on the earth with which the lunar craters may be compared is Meteor Crater in north-central Arizona.[1] Involving complex problems in kinetics, mechanics, meteorology and geology, this was declared, by the great Arrhenius, to be the most interesting spot on the earth.

The present concern is with the impacting body, meteorite or comet, and the disposition of its energy and mass, and also with the effects and phenomena of the impact. This requires a fair description of the crater-basin in all its features.

We do not know if the impacting body in this Arizona encounter was a member of our solar system, only a belated planetesimal, or was a visitor from interstellar space arriving in haste unannounced and without credentials.

This crater is a great circular basin, in hard rock

[1] G. K. Gilbert, SCIENCE, 3, 1896; D. M. Barringer, *Proc. Acad. Nat. Sci. Phila.*, December, 1905; B. C. Tilghman, *ibid.*; H. L. Fairchild, Geol. Soc. Amer., *Bull.* 18, 1907, and SCIENCE, 72, 1930; Eliot Blackwelder, SCIENCE, 76, 1932; Clyde Fisher, Amer. Mus. Nat. Hist., Guide Leaflet Series, No. 92.

strata, now 4,000 feet in diameter and with a depth of 600 feet, of which about 150 feet is due to uptilt of the rock rim. An inwash filling has average depth of about 80 feet. The rock strata belong in the Grand Canyon series. In descending order, with approximate thickness they are, Moencopie red sandstone, 40 feet; Kaibab limestone, 260 feet; Coconino white sandstone, 950 feet.

At the time of impact the spaces and interstices of the upper strata were filled with air and water, while the Coconino sandstone was saturated with water.

The tremendous concussion shivered the rocks to dust for a depth 1,200 feet or more.

The underground form of the shivered rock was that of a "cone of percussion." Taking the angle of the cone as ninety degrees and assuming that the impacted area on the surface of the plain was a circle of 1,000 feet diameter, then the downward enlargement of the cone would, at the depth of 1,200 feet, give a diameter of quite 3,500 feet.

The short-wave vibrations pulverized the quartz grains of the Coconino to microscopic dust and produced heat sufficient to fuse some of the quartz into silica glass.

The water in the pulverized and vibrating mass was instantly changed to superheated steam, and the violent expansion lifted not only the crushed rock but also the overhanging shattered strata and piled part of the mass on the plain, while the larger part fell back into the instantly created basin.

Further explosive effect uptilted the topping strata of the basin rim. During subsequent time the upper portion of the walls has receded somewhat by weathering, as indicated by the talus slopes. The remnant of the tilted strata has a maximum upslant of about 150 feet.

The ring of rock debris on the crater rim is a great ridge with a basal width of nearly one-half mile. It consists of quartz flour, the powdered Coconino sandstone and fragments of Kaibab limestone. Larger blocks of the latter have been estimated in weight up to 4,000 tons, and huge blocks of this limestone lie a mile from the crater. The ridge of debris has been reduced in volume by rain and wind erosion.

The amount and weight of rock expelled from the crater-basin is fairly determined. Drilling in the crater penetrated 800 feet down to the red Supai sandstone, of which 80 feet is inwash filling. The 720 feet deducted from 1,250 feet, the depth of the three rock formations, leaves 530 feet as the depth of the primitive crater basin below the surface of the plain. The same figure is found by deducting 150 feet of uptilt of the rock rim from the 600 feet of basin depth and adding the 80 feet of inwash filling.

The expelled rock was a discoid of stone with diameter about 3,500 feet and thickness of 530 feet. The weight was about 400,000,000 tons. The energy expended in tossing this mass to the plain was a minor portion of the energy transferred from the meteorite to the earth.

Transformation of Energy

The dynamics involved in the production of the crater give a fine illustration in conservation and transformation of energy. The resident energy in the falling meteorite, mass-motion, was partly transferred to the earth and transformed into vibratory motion. This was all transformed into molecular motion or heat and this was retransformed through steam expansion into mass motion, the lifting of the great mass of rock through hundreds of feet against the force of gravity. To-day part of that energy is stored in the great ring of rock rubbish on the rim of the crater as potential energy, by virtue of its uplifted position.

All the kinetic energy of the meteorite was not transferred to the earth, as a large part was used in its self-explosion, noted below. The collision, the transformation of energy, the explosion deep in the earth and the bursting of the meteorite all occurred in a second of time.

Some of the substance of the meteorite, exploding simultaneously with the crater eruption, is found in the crater filling.

Canyon Diablo Irons

On the plain surrounding Meteor Crater in a radius of four to five miles have been found thousands of nickel-iron meteorites, the Canyon Diablo siderites. They range in weight from 1,406 pounds down to tiny individuals of a few grams. Their character, number, size and association make this "fall the most famous and interesting in the literature of meteorites."

The irregular form of the irons, with great angularity and sharp cusps and ridges, shows that they were nodular accretions in a non-metallic substance, probably meteoritic stone. It appears likely that most if not all solid iron meteorites were originally inclusions in stony matrix. The Willamette iron in the American Museum of Natural History with its perforations is a fine example. The genetic relationship of the Canyon Diablo irons to Meteor Crater is positive. The irons were nodular inclusions in either the giant meteorite or in stony masses which were attached to the great nucleus. Stone-like meteorites, the aerolites, are highly perishable, and exposed to air and water dissolve and disappear. The giant meteorite and its companions, if it had such, undoubtedly were largely stony substance which disappeared thousands of years ago, leaving the irons and the crater features as the record. It has been suggested that the irons were

unattached or free companions of the meteorite. This idea probably is in error. The irons with their stony casings did not fall directly from the sky or vertically. Such fall would imply that the thousands of bodies had been traveling through space as a great open swarm or cluster ten miles in diameter; which would seem impossible. Gravitation would draw the bodies together into a close, compact mass. Atmospheric obstruction during their fall to the earth could not so widely separate the units. The impact of such assumed close aggregation would have quite the same effect as if it were one solid body. The kinetic energy changed instantly to heat produced expansion with violent explosion which distributed the entire mass over a circle of five miles radius. The sharp edges and angles of the nickel-irons prove that they were not heated sufficiently to produce any fusion. This fact is also emphasized by the occurrence of innumerable minute irons.

FATE OF THE METEORITE

The fate of the meteorite is the interesting and important question. This has already been suggested in the explanation of the Canyon Diablo irons.

Exploration of the crater was made in the belief that a great nickel-iron mass lay buried. This is mechanically impossible.

Physicists claim that in the sudden stoppage of a great meteorite with planetary velocity, the kinetic energy, mass motion, would produce heat sufficient to vaporize the mass. This appears to assume that all the energy is expended upon the mass itself. But at Meteor Crater all the enormous energy represented in the crushing of the strata and the expulsion to produce the basin was transformed energy supplied by the meteorite. The explosion of the meteorite was in quite the same instant of time as the impact and concussion. A moment later came the piling on the plain of the disrupted rock. It is probable that some part of the meteorite lies beneath the great ring of rock debris surrounding the crater. Such burial probably has preserved some meteoritic stone of which the meteorite was mostly composed.

In any physical and mathematical study of the transformed energy the enormous amount consumed or utilized in the expansion, and in the projection and spreading of the mass over the area of ten miles in diameter, must be recognized, as well as that utilized in the production of the crater phenomena.

If the impacting body was a spherical siderolite, of 1,000 feet diameter, and with an average density of 4.0, then its weight was 65,450,000 tons.

LUNAR CRATERS OF IMPACT ORIGIN

The lunar craters are mostly deep depressions below the general surface, even to a depth of 10,000 feet, and it is now recognized that the lunar depressions are impact craters, produced by the infall of bodies of undetermined nature and velocity. Many of the craters have a central cone, a feature readily duplicated in experimentation. The sharp-pointed or spire form is undoubtedly due to spalling or exfoliation of the massive original columns, caused by expansion and contraction of the lunite under the extremes of temperature.

The multitude of craters and ringed plains many thousands in number, sometimes closely crowded and overlapping and of varying size up to fifty miles or more in diameter, is a remarkable and strange display, but this is precisely the condition and appearance theoretically required during the early stage of planetary growth by ingathering of planetesimals.[2]

The moon is ocular evidence for the cold accretion element in the planetesimal hypothesis.

FATE OF LUNAR PLANETESIMALS

Between Meteor Crater and the lunar impact craters there are great differences, due to the uncompacted character of the lunar surface material and to the varying size of its impact features, ranging from barely visible pittings up to ringed plains with diameter of sixty miles. Planetesimals are supposed to have ranged in size from dust particles to bodies the size of planetoids (asteroids). The most striking feature is the close crowding and even overlapping of hundreds of craters, yet retaining perfect form. The absence of non-circular forms has been noted as an objection to the impact theory.

Two significant elements in the lunar landscape are the high topographic relief of the crater ridges and basins, and the clearness of the surface details, especially the irregularity and asperity of the circular ridges. If the infalling planetesimals were vaporized, then in the areas where the craters are closely crowded, the thick mantle of precipitated planetesimal substance would certainly bury the surface details and at least partly fill the basins. Only the younger craters would remain uncovered and distinct. This appears definitely to rule out the conception of vaporization of the infalling bodies. The crater forms with the depth of the basin suggest that the planetesimal produced a splash in the uncompacted lunite and, passing downward with its energy transformed to heat, was engulfed as a molten body in the lunite; a revulsion producing the central cone. The velocity of the impacting body is an undetermined critical factor. It is assumed that all the planetesimals were traveling

[2] The term meteor refers to the atmosphere. A body falling through the atmosphere we call a meteor. As the moon had no atmosphere it had no meteors. For its accretionary infalls we have no better name than planetesimals.

in the same general direction with the earth and moon, and were captured by the attraction of the planets in some sort of overtake and intake. The acceleration of the velocity of infall due to gravitation except on close approach was on the moon only one eightieth of that of the earth.

The remarkable central cones are quite certainly an effect of the recoil, revulsion or upthrow of liquid or semi-liquid from violent disturbance. In experimentation this feature results with burial or engulfment of the missile. The level smooth floors of the majority of craters suggest liquidity.

From this brief study it would appear certain that the planetesimals were not vaporized. Their stoppage was unlike that of the Meteor Crater bolide. They plunged deeply into the incoherent lunite before their energy was entirely changed to heat. Free explosion in the deep inclusion was inhibited, but fusion occurred, of both the planetesimal and the enclosing lunite. Under this conception all the moon's substance passed through a state of fusion. This would give the lunite the dark color and resemblance to terrestrial lava and scoria.

LUNAR PLAINS

The larger part of the moon's surface is comparatively or entirely destitute of craters. These relatively smooth areas were called "seas" or "maria," under the mistaken conception that the moon once had atmosphere and ocean. The striking contrast between areas covered with craters and adjacent areas quite or wholly destitute of craters would seem on first thought to be fatal to the accretion theory. The volcanic conception did not explain this discrepancy.

It must be supposed that the infalling planetesimals were quite impartially distributed over the lunar surface. The present difference must be due, not to unequal infall but to destruction of the impact features. For this we may not invoke external or cosmic agency but must recognize some force or process within the moon itself. An evident internal force is gravitation with condensation and contraction process. With a radial depth of over 1,000 miles and the loose texture of the lunite, there must have been considerable subsidence of the lunar surface. The maria are such areas of depression below the general surface. The large irregular areas, comparatively destitute of perfect impact features, yet carry many remnants of broken-down crater rims. They probably are the areas of surface subsidence since the moon became of age. The structure and behavior of the porous and brittle lunite were so different from that of the earth's solid crust that the peculiar mechanics are difficult of interpretation. It appears that some factors have largely but not entirely shattered or broken down the crater topography. A few craters in good form on the wide plains are record of planetesimal infall subsequent to the areal subsidence.

Some of the borders of the plains are depressed alongside of mountain ridges, a relation similar to differential vertical movement or faulting on the earth. Such relations are the natural effect of local subsidence.

The large circular areas, "ringed plains," probably are the impact areas of great planetesimals. The great variation in size of the records of impact, from minute pittings up to the "Mare Imbrium" 700 miles in diameter, is the normal record of planetesimal infall.

The variety of singular forms and markings on the lunar surface, never explained under volcanism, will probably find explanation as the peculiar effects of planetesimal impact and explosion.

Stages in the cosmic history of the lunite: 1. Existence in the sun for a near-eternity of time, as superheated vapors of all known elements. 2. Removal from the sun with distribution far out in interstellar space, with subjection to absolute zero temperature. 3. Motion in orbital revolution around the parent body, with loss of heat and condensation to liquid state. 4. Continued cooling and condensation to solid state, as planetesimals of size from molecules to masses like the asteroids. 5. Collision with the moon, probably producing a second state of fusion. 6. Cooling and condensation to solid lunite. 7. The latter infall exposed to human vision through 240,000 miles of space and subjected to human cogitation.

THE JUVENILE EARTH

The earth had its inception, perhaps it might be called its embryonic stage, as one of the larger masses of the planetesimal swarm. It grew by drawing to itself the other and smaller planetesimals that drifted within the range of its gravitational control, through the crossing of their orbits.

An important question at once arises as to the temperature of the infantile earth. It may be conceded as a possibility that the initial mass had high temperature. Such conception would imply that either the mass or knot of superheated material which served as the nucleus of the young earth had retained its heat from the far time of solar outpouring or that the accretionary process began promptly after the dynamic encounter. This might explain, in part, the supposed present very high temperature of the earth's interior. However, the length of time that must have been required for the young earth to gather in any great amount of material would have allowed the smaller planetesimals, traveling through a vacuum and absolute zero temperature, to lose their heat. But the much greater immensity of time required for the larger growth quite certainly implies cold accretion.

Whatever was the temperature of the infantile earth, the planetesimals that formed it must have been similar in composition or substance to those which later built the mature earth. They contained all the various elements which compose the earth and its envelopes. This rules out the fanciful idea that the earth's core is nickel-iron and that the globe is built of concentric layers of diverse composition. This conception of concentric structure appears to rest in the belief in an originally molten globe which was inherent in the discarded nebular hypothesis.

The temperature of the earth's interior in distribution and degree and perhaps in cause is yet undetermined. We do not know if the earth is gaining or is losing heat. To determine this, precise measurements are required through centuries of time. If we may assume that physicists in the far future will have scientific curiosity and intelligence, it would be a fine bit of altruism for living geophysicists to make and record precise temperatures in deep drillings, in areas and under conditions that may be exactly duplicated centuries hence.

The juvenile period in the earth's development endured until the earth, in its growth, had acquired gravitative force sufficient to hold an atmosphere and primitive ocean. This ability was probably attained when the earth was about the size of Mars or with one ninth of its present mass. During this early stage of planetary growth, the surface of the planet probably was similar to that of the moon. The absence of air and water on the moon has permitted preservation of its surface features through the untold eons of time since the latest planetesimal bombardment. Under the planetesimal view the earth's core, about 4,000 miles diameter, is the original planetesimal substance, minus a large portion of its occluded gases, with chemical recombination and molecular readjustment under the enormous compression of eight ninths of the earth's mass.

GROWTH OF THE GLOBE

As the larger earth grew in mass and gravitative power it had increasing grasp on the flying planetesimals. The accretion was accelerated as long as the planetesimal supply was abundant; but the later growth of the globe had decreasing rate of accretion.

During the long stage of rapid accretion the earth's surface was in a state of great disturbance. The infalling planetesimals produced great splashing of the water bodies and tremendous concussion on the land areas.

The stony planetesimals that fell on the land surfaces were only less promptly hydrated and dissolved than were those which fell in the seas. With the planetesimal accumulation there was mingled the modified materials, volcanic eruptives and aqueous sediments. In deep burial the mixed materials were subjected to pressure, to heat and molecular reorganization. Eventually at lesser depths in the completed globe, this earth stuff has been highly differentiated into metallic segregations and the varieties of lava. A striking product of differentiation is found in the enormous amount of crystalline quartz, represented in all the metal-bearing quartz veins, in all the sandstones and quartzose rock and in the sand beaches of all the sea and lake shores of the world.

Great activity and change within and on the earth did not cease with the completion of its volume. It has continued restless like a living organism. Its dynamics and phenomena challenge human intelligence, and interesting and important problems are yet subjects of study. The writer, in bygone years, discussed geologic problems under the planetesimal conception.[3] One of those problems now requires further consideration, with change.

BEGINNING OF LIFE

If life was initiated through chemical and physical action from inorganic matter, under control of solar energy, the physical conditions in degree of heat and moisture requisite for life processes were fulfilled when the earth had acquired volume and depth of atmosphere sufficient to conserve the solar heat. The planet Mars, with a diameter of 4,215 miles, somewhat more than one half of the earth's diameter, has a thin atmosphere with some water, but it is doubtful if the surface temperature is sufficient for either initiation or development of life as we know it. Perhaps the suitable conditions existed on the earth when its diameter was 5,000 miles, and it had about one fourth of its present mass. However, an inhibiting factor must be recognized. While the earth was acquiring three fourths of its total mass the accretionary process probably was accelerated so that the surface was continually mantled with fresh accumulation. And whether the material was partly of large planetesimals producing great commotion, as noted above, or was largely of planetesimal dust and minute bodies, as Chamberlin suggested, the conditions were unfavorable for life development.

However, when the earth was nearly full size, the accretionary process was slow, and slowing, then the physical conditions certainly were favorable for life. That relatively short span of pregeologic time yet must have been sufficient for the evolution from primitive life-substance to the highly organized animal life represented in the oldest unaltered geologic deposits.

[3] H. L. Fairchild, *American Geologist*, 33: 94–116, 1904; Geol. Soc. Amer., *Bull.* 15: 243–266, 1904; SCIENCE, 64: 365–371, 1926.

The philosophic claim is made that a single life germ might hold all the potency and promise of the entire organic world. But why restrict the beginning of life to a single germ? And why restrict the organic synthesis to one occasion? No good reason appears for supposing that the combination of forces on the surface of the mature earth was ever essentially unlike the present, and the circumstances which produced the primordial life must have been constant. This implies the probably continuous creation of organic matter to the present time. The amoeba either has retained its simplicity through countless generations of organic evolution during a vast length of time or it is of recent creation.

SCIENTIFIC EVENTS

INTELLECTUAL FREEDOM

THE following manifesto signed by 1,284 scientific workers, of whom sixty-four were members of the National Academy of Sciences, and eighty-five college presidents and deans and directors of industrial laboratories and experiment stations, has been issued:

In an article entitled "The Pragmatic and Dogmatic Spirit in Physics," which appeared in the April 30 issue of *Nature* (with strong editorial disapproval), wide publicity is given to the official Nazi position on science and scientific research. In essence the article is an attack on all theoretical physics, and, by obvious implication, on scientific theory in general. It introduces the official racialism of the Nazis to divide physicists into good, *i.e.*, non-theoretical and "Aryan," and bad, *i.e.*, theoretical and Jewish. Similar notions have appeared in many popular magazines and scientific journals in Germany, in the addresses and writings of the Minister of Education, of university rectors and deans, of scientists and non-scientists. Apart from racial theories, furthermore, science and art are subject to ruthless political censorship. These ideas have found concrete expression in the dismissal and persecution of over 1,600 teachers and scientists (by the fall of 1936) from German universities and research institutes (and now Austria and Italy too), and in the restriction of higher education to students having the "proper" political and racial qualifications.

American scientists, trained in a tradition of intellectual freedom, hold fast to their conviction, that, in the words of the resolution adopted by the American Association for the Advancement of Science, "Science is wholly independent of national boundaries and races and creeds and can flourish only when there is peace and intellectual freedom." If science, to quote the A.A.A.S. resolution again, is to continue to advance and spread more abundantly its benefits to all mankind—and who can attack that goal?—then the man of science has a moral obligation to fulfill. He must educate the people against the acceptance of all false and unscientific doctrines which appear before them in the guise of science, regardless of their origin. Only in that way can he insure those conditions of peace and freedom which are essential for him and for the progress of all mankind.

It is in this light that we publicly condemn the Fascist position towards science. The racial theories which they advocate have been demolished time and again. We need only point to the work of Heinrich Hertz in physics, Fritz Haber and Richard Willstätter in chemistry, Ludwig Traube, Paul Ehrlich and August Wassermann in biology and medicine, all German Jews and all empirical scientists. The charge that theory leads to a crippling of experimental research is tantamount to a denial of the whole history of modern physics. From Copernicus and Kepler on, all the great figures in Western science have insisted, in deed or in word, upon the futility of experimental research divorced from theory.

We firmly believe that in the present historical epoch democracy alone can preserve intellectual freedom. Any attack upon freedom of thought in one sphere, even as non-political a sphere as theoretical physics, is in effect an attack on democracy itself. When men like James Franck, Albert Einstein or Thomas Mann may no longer continue their work, whether the reason is race, creed or belief, all mankind suffers the loss. They must be defended in their right to speak the truth as they understand it. If we American scientists wish to avoid a similar fate, if we wish to see the world continue to progress and prosper, we must bend our efforts to that end now.

THE ASSOCIATION OF SCIENTIFIC WORKERS

THE resolution of the American Association for the Advancement of Science (SCIENCE, February 4, 1938) and recent actions of the British Association bear witness to a widespread interest on the part of scientific workers in the increasingly critical development of social problems. Members of the staff of Harvard University, the Massachusetts Institute of Technology and other institutions in Boston and Cambridge, Mass., have formed an Association of Scientific Workers, having as its aims: (1) to bring scientific workers together to promote an understanding of the relationship between science and social problems, (2) to organize and express their opinions on the steps to be taken towards the solution of these problems, (3) to promote all possible action on the conclusions reached.

The contribution of scientific workers to world progress is to-day larger than ever before. Nevertheless, they are faced with economic and international developments which continually become more critical. As a group they have virtually no control over the applications of science, and are without the means of expressing their opinions as to how these developments should be met. The only expressions of opinion