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OUR WORLD IN THE MAKING

An example of innate conservatism, in science instead of religion, is found in the tenacity with which even scientific men are holding to a discredited hypothesis of world origin. It is now one quarter of a century since Professor T. C. Chamberlin, with the cooperation of Professor F. R. Moulton, proved that the nebular or Laplacian hypothesis for the evolution of the solar system fails at all points where it is tested by modern physical science. With the passing of the old philosophy, for the nebular cosmogonic guess was more philosophy than science, there should be abandoned the involved conception of an originally molten globe. This conception has always been a hindrance to geologic science, because most of the difficult problems in geology make the final appeal to the manner of formation, or to the initial condition, of the globe.

Instead of an initial and incandescent globe of full size the Planetesimal theory, by Professor Chamberlin, builds the earth by the slow infall and accretion of cold particles (planetesimals), with the surface of the growing globe always solid and comparatively cold. This new conception gives a better basis and more satisfactory explanation for the elusive puzzles in earth science.

This paper is not in discussion of the origin of the solar system, but it is a brief comparison of some geologic problems analyzed under the two views of the primitive earth. The cosmic process in evolution of sun and planets is a study in mechanics, physics and mathematics, and lies in the domain of astrophysics. But the formation of the globe, from its primitive condition, should be revealed in the constitution of the globe itself. The earth should have inscribed its own autobiography, and the study of such record is the province of geology. In former time the young, modest and persecuted science accepted the cosmic philosophy of Swedenborg and Kant, and the deductions by Laplace from imagined conditions, along with the involved idea of a primitive, superheated and liquid globe. The progress of geology, especially on its theoretic side, has been seriously handicapped by its deference to a mistaken geogony.

With the purpose of presenting the subject to the general reader in a single article, the facts, arguments and implications are necessarily given with brevity and incompleteness and as untechnical as possible. It is expected that experts will find occasion for criticism. Brevity is quite compulsory for the nebular column, because the conditions, surficial and internal, of a "globe of fire" are beyond the limits of our knowledge, and we can only surmise. The increasing knowledge of matter and energy, as revealed in star and atom, may eventually give some conception of what should be the behavior of earth-stuff under enormous pressure in the interior of a molten globe.

The writings of Chamberlin and Moulton in criticism of the nebular hypothesis, and in construction of the planetesimal, are in the *Journal of Geology,* volume 5 and later volumes; the *Year Books of the Carnegie Institution of Washington,* volumes 2 to 21, 1903–1923; *Astrophysical Journal,* 1900 and later; Chamberlain and Salisbury's "Geology," volume 2; "Origin of the Earth," by T. C. Chamberlin, Chicago, 1916; Moulton's "Introductory Astronomy."

On the geologic bearings of the planetesimal theory, the evolution of the earth, consult the *Journal of Geology,* volume 21 and later; the text-books in geology by Chamberlin and Salisbury; LeConte's "Elements of Geology"; *Bulletin of the Geological Society of America,* volume 15 (1904), pages 243–266.

PROBLEMS IN GEOLOGY

Under the nebular hypothesis	*Under the planetesimal theory*
(1) INTERNAL HEAT	
Is chiefly residual, or inherited from the primitive molten state. It being assumed that the high temperature of the solar nebula was partly retained until the earth-moon ring was gathered into the globe.	Is an effect of gravitational compression, with involved physical and chemical reactions, and possible radioactivity. The pressure was not exerted on matter of original high density, but on the porous accumulation of cold matter of the ingathered planetesimals. These "may have been either atoms, molecules or aggregates." It is uncertain if the present temperature of the earth as a whole is rising, falling or stationary.
(2) GROWTH AND SIZE	
Growth was completed, or full size attained, while the collected material was yet extremely hot, and the surface was liquid rock; over which lay an envelope of mineral vapors.	Beginning as a larger knot of the scattered solar matter the globe grew slowly by accretion of cold materials, through vast duration of time. The hypothetical stages, as conceived by Chamberlin, are described in his writings, especially in volume 2 of the "Geology."
(3) SURFACE TEMPERATURE	
The retained cosmic heat is assumed to have been sufficient to hold all the earth-stuff in the molten state. The liquid globe was surrounded by an envelope of heavy vapors, and radiation of heat was slow.	The earth's surface was always solid, and comparatively cold, especially in the later stages of growth. In the early stages of accretion, with possibly rapid infall, and production of some heat by the impact, the absence of an atmosphere favored rapid radiation. In later stages of growth and slower infall the larger surface of the sphere aided radiation of heat.
(4) DENSITY; POROSITY	
In a liquid globe no porosity appears admissible. Density was always at the maximum, for the depth.	The ingathered planetesimals held all the substances of the earth, air and sea. With the slow accretion of cold matter, sifting down through the atmosphere in the later stages of growth, a high degree of porosity appears inevitable. Hence the surface density was always low.
(5) STRUCTURE	
Fluidity permitted free convection, and favored homogeneity, or uniform density at equal depths. This implies the sinking of the heavier substances and the concentration of metallic alloys in the earth's central mass. This fully accounts for the high density at the earth's center.	Accretion of cold and varied materials, with probably irregular infall, produced heterogeneity of the earth's mass; with variable initial density and probably with irregularity of the surface. (See items 6 and 7.) Heating of the interior mass eventually might permit some convection and settling of the heavier substances toward the center of the sphere. This may partially account for the high density of the earth's core.

(6) PRIMITIVE SURFACES

On a molten globe a perfect fluid level is inevitable.

Surficial inequalities are probable in all stages of growth (items 5 and 7), because of the irregular accretion of the planetesimal matter in kind, space and time.

(7) ORIGIN OF CONTINENTS AND OCEANIC DEPRESSIONS

One view holds that the inequalities of the earth's surface were initiated by unequal cooling and solidification of the molten surficial material; the first-called areas becoming the continents, and the later areas to solidify being the ocean "basins." (See the writings of James D. Dana and Joseph LeConte.)

Another modified view initiates the inequalities by the unequal contraction of the earth's mass, from the center outward.

These views appear inconsistent with items 4 and 5.

Water was probably held in the depressions of the earth's surface in the later stages of growth; and quite certainly when the globe was somewhat larger than the planet Mars.

With atmospheric weathering of exposed areas, and the concentration of the heavier solubles in the seas, a somewhat greater density was given the suboceanic areas. Under the principle of isostasy this difference was self-perpetuating (items 11, 12).

(8) THE FIRST ROCKS

These were igneous and crystalline, made by the cooling and solidification of the surficial materials; these being silicates, of inferior density.

The first non-igneous deposits were the precipitates of minerals which had been held in solution in the hot ocean (see the writings of T. Sterry Hunt, in Proc. Amer. Assoc. Adv. Science, vol. 20 (1871) pages 1–59).

But no such chemical precipitates have ever been found.

Weathering and sedimentation processes became active when the globe was larger than Mars. Hence the earliest sedimentary rocks, mixtures of planetesimals, of aqueous, eolian, volcanic and possibly organic materials, are deeply buried in the earth's mass by the subsequent growth of the globe (see items 16, 17, 19, 21).

(9) EARTH CONTRACTION; SHRINKAGE

Shrinkage of the globe, or increase in density, is attributed primarily and chiefly to loss of heat. Such contraction was mostly by crustal consolidation, the change from liquid to solid.

A possible minor factor in contraction is the reorganization of deep-seated matter under great pressure and heat.

The amount of earth shrinkage by heat radiation during geologic time is certainly negligible.

Considerable shrinkage during geologic time (item 20) is an evident fact (item 10), and no effective amount can be credited to loss of heat.

The contraction may be attributed to the condensation of the loose or porous accretionary matter, especially of the external portion of the globe (item 4); also to the expulsion of the volatile substances which have made the hydrosphere and atmosphere (items 11, 13).

Molecular reorganization of the deeply buried matter may be recognized as contributory.

(10) CRUSTAL SHORTENING; MOUNTAIN SYSTEMS

The great existing mountain systems prove the horizontal mashing of thick rock strata during very recent time. But heat radiation during geologic time is not an efficient factor in earth shrinkage.

Increase of density by the reorganization of matter in the earth's core does not appear to be quantitatively competent.

Some elimination of occluded gaseous matter may be possible. (Item 11.) See the writings of J. D. Dana and Joseph LeConte.

All the great mountain systems of the globe have been made since the earth attained its present condition, and mostly in the latest geologic periods. It has been estimated that on any great circle of the globe the horizontal shortening, involved in mountain folding and compression faulting, must be at least one hundred miles.

The factors in later contraction noted above (item 9) may be competent to produce this contraction, which is not large when compared with the circumference of 25,000 miles.

(11) ORIGIN OF ATMOSPHERE AND OCEAN

Most of the volume of the present atmosphere and hydrosphere must have been in the vast vaporous envelope which surrounded the incandescent globe.

Such volatile materials as were held, occluded, in the liquid rock must have

The volatile substances which had been entangled in the ingathered planetesimals were gradually forced surfaceward by the increasing pressure and heat in the growing globe (item 13). In earlier stages of the earth's growth the lighter been mostly expelled from the crustal mass during the process of solidification, judging from the behavior of modern lavas.

Some later elimination of occluded gases, in minor amount, may be admitted. (Item 13.)

gases must have been lost into interplanetary space, because the gravitational attraction of the diminutive earth was, like the moon, incompetent to hold the flying molecules. But when the earth attained a mass somewhat larger than Mars it acquired a primitive atmosphere of the heavier gases. Eventually water vapor was retained, and its condensation produced the hydrosphere.

The air and water are the perspiration of the globe.

(12) Volume of Atmosphere and Hydrosphere

The earth's envelopes, air and water, must have been quite at the maximum while the globe was yet hot at the surface. Minor addition in later time might be from some occluded materials in the deeper magma.

The important fact is that the earth was full size before the atmosphere and hydrosphere were created.

The great volume of water expelled from volcanoes must be regarded as meteoric (item 13).

It has been thought that the hydrosphere is now decreasing, due to absorption in the crust of the cooling globe.

Volcanoes are the vents for expulsion of the volatile materials from the earth's interior. Less conspicuous outlets are the fumaroles, solfataras and carbon-dioxide springs, like the Grotto del Cane, near Naples, Italy. It is evident that the process of expulsion is yet very active, and the earth's envelopes are in receipt of large accessions.

When the globe was small a large part of the expelled volatiles were lost, and even to-day the earth appears unable to retain gases of highest molecular velocity. Whether the supply to the air now balances the losses is not known.

It appears, therefore, that the present envelopes do not contain nearly all the volatile matter which has been forced from the earth's interior. Some accessions have possibly been obtained from interplanetary space. The hydrosphere and atmosphere are the net product of complex activities during eons of time.

(13) Volcanism

The water of volcanoes, enormous in volume, has been regarded as meteoric, or as derived from the hydrosphere. It is assumed that the water finds its way down to the volcanic reservoir even against the pressure and heat which produces the violent expulsion.

The alternative view is to suppose that much of the present air and water was held, in occlusion, in the molten magmas; for volcanism has been active during all geologic time. But the conception of a primitive molten globe has not been favorable to the idea of an immense volume of occluded magmatic gases. However, the basins on the moon, some of great size, have been attributed to intense volcanism.

Volcanic gases of the various kinds, water the most abundant, are magmatic. They were part and parcel of the cosmic stuff of which the earth was built. They are forced surfaceward by the pressure and heat of the interior.

Volcanism was probably most active during the stages of growth preceding the geologic record of the sedimentary rocks. (The theoretic stages are given by Professor Chamberlin in volume 2 of the "Geology." The lunar craters resemble craters of impact, like Meteor Crater in Arizona (see papers by D. M. Barringer; also Bull., Geol. Soc. Amer., vol. 18, pages 493–504).

If lunar craters are the effect of impacts, and due to the infall of massive planetesimals, it gives interesting suggestion as to the character of some of the earth-moon stuff.

(14) Genesis of Vein Minerals

The postulate of a molten globe has not favored the existence of great volume of interior, or magmatic, volatiles. Hence the ascending heated vapors and liquids responsible for many mineral deposits have been credited to

Mineral deposits associated with eruptive phenomena are mostly attributed to superheated vapors and fluids. Quartz veins carrying metals are clear examples of the work of ascending superheated water. Such process previously descended meteoric waters.

implies large volume of magmatic volatiles in the earth, below the reach of meteoric waters.

(15) SURFACE, OR EPIGENE, AGENCIES

Geologic processes on the earth's surface, as seen in action to-day (rain, river, wind, frost, etc.), could not have come into effect until the earth and its hot ocean had cooled down to a temperature comparable to the present. Hence epigene processes are definitely limited to the latest phase of the earth's history.

When the atmosphere and the primitive seas came into existence, with the globe larger than Mars, the surficial geologic processes began. All the epigene activities, including the chemical, and possibly the biologic processes, were in operation while the juvenile earth was growing by the abundant infall of planetesimal matter (items 16, 18, 21).

(16) BURIED SEDIMENTARY ROCKS

All the rocks produced by epigene processes, the stratified and sedimentary, must be superficial; and should be mostly visible and unaltered. Immediately beneath the observable base of the sedimentaries there should be found either the primitive igneous rocks of the cooling crust, or the precipitates from the hot ocean (item 8).

Stratified or sedimentary rocks, comparable to the sands and clays of to-day, were deeply buried in the earth during the later stages of the growing globe. And with these deposits were mingled the infalling planetesimal matter, and probably organic substances (items 17, 19, 21).

Under the conditions of heat and pressure produced by the subsequent burial of those early sediments they have been altered (metamorphosed) into what we call igneous rocks.

(17) SOURCE OF ATMOSPHERIC CARBON-DIOXIDE[1]

Under the former view, involved with the nebular hypothesis, all the CO_2 was originally held in the primitive atmosphere.

Under any modified view of later supply to the air, from volcanic sources, it must yet be admitted that the initial atmosphere should have been too rich in CO_2 to permit of the conditions of climate and of life which certainly existed far back in Precambrian time (items 18, 21).

Like all the volcanic gases the CO_2 is magmatic, and has been continuously supplied from the earth's interior since some very early stage of the growing globe.

Ever since the hydrosphere existed a withdrawal of CO_2 from the air has been in action, by the storage in the rocks, ocean and organisms. It may not be supposed that these two opposing processes were always balanced. Perhaps decided unbalancing initiated climatic changes (item 18).

The present content of the atmosphere is the net result of complex physical, chemical and biologic processes since the earth was about the size of Mars.

(18) ANCIENT CLIMATES

Because of excess of CO_2 and of water in the atmosphere of early geologic time the ancient climates should have been hot, humid and suffocating for all animal life.

The slow withdrawal of the CO_2, by storage in the earth, has slowly produced our present sky conditions. Hence world climate has slowly and steadily changed from hot to cold. And the Glacial Period is a premonition of the final refrigeration.

It is now certain that glaciation has often occurred in the past, even far back in Precambrian time (see "Ice Ages, Recent and Ancient," by A. P. Coleman, New York, 1926). This was long before the storage of vast amount of carbon in the limestones and coals of the Paleozoic era. And there have been later epochs of cold and aridity, particularly in the Permian Period. Such conditions demand thin and transparent atmosphere.

The fossils of the Cambrian indicate that

[1] To-day the CO_2 constitutes one part in three thousand of the atmosphere. But the ocean is the storehouse of the gas, holding, it is estimated, eighteen times as much as the air. The oceanic content was probably derived from the air by carbonation of the crystalline rocks. Certainly all the carbon now stored in peat and coal, in limestones and marble, and in living plants and animals, has been withdrawn from the atmosphere. The amount of carbon tied up in the carbonaceous deposits and the calcareous rocks has been estimated as twenty thousand to thirty thousand times the present atmospheric content.

the sky conditions in that ancient time were comparable to the present. And the entire geologic record, in rocks and fossils, shows that world climates have always been similar to the present.

(19) ORIGIN OF HYDROCARBONS

Because the interior or magma of an originally molten globe could not retain large quantity of volatile substances it is necessary to attribute petroleum and rock gas to some surficial source or process. Hence the hydrocarbons have been wholly credited to organic origin. It may be admitted that the substance of plants and animals originally held in limestones and shales have been in some cases expelled and reservoired in porous sandrocks.

While the above explanation may be conceded for many of the oil and gas fields, it is not entirely satisfactory for some localized reservoirs of great volume; nor for the peculiar relations in the "salt domes" of the Gulf coastal plain; nor for the association of the hydrocarbons with crystalline rocks and volcanic phenomena.

All the elements of rock-oil and rock-gas, as well as those of all plants and animals, were originally in the cosmic matter, the planetesimals, and were buried in the growing globe. In time they were partially expelled, along with other volatiles, and eventually the C, H, O and N became the substance of organisms.

These elements are yet being extruded from the earth, and against the magmatic origin of the hydrocarbons there is only a negative chemical argument.

But granting the exclusive organic genesis of the compounds there is yet a valid compromise explanation. If life existed on the earth when the globe was much smaller than to-day (item 21), and it certainly existed in pregeologic time, then organic matter became deeply buried in the ancient deposits.

There may be three immediate sources of the hydrocarbons: (1) from organic material in recent strata; (2) from organic material in deeply buried pregeologic deposits; and (3) from the original planetesimal materials.

The hydrocarbons associated with volcanism may be from either (2) or (3).

(20) LENGTH OF GEOLOGIC TIME[2]

Geologic time, or the reign of formative epigene processes, comparable to those at present, is strictly limited to the time since the globe cooled to a surface temperature somewhat like the present tropics.

Estimates of such duration by physicists and astronomers range from ten to one hundred million years. Geologists and paleontologists have not found this long enough to produce the succession of rock-strata and the evolution of life.

Epigene processes probably were effective when the globe was somewhat larger than Mars. Hence Precambrian time was of vast duration, covering not only eons while the earth was gathering its mass, but also the great length of time since growth was completed, but preceding the Cambrian, or the clear stratigraphic record.

Geologists estimate time since the Cambrian as at least one hundred million years, and since epigene agencies and life began as perhaps one thousand million years. It is only a guess. But under the planetesimal theory the student of earth science can reasonably claim all the time he needs.

(21) LIFE ON THE EARTH

Origin of life on the earth is limited to the time since the globe cooled to a condition similar to the present time.

Precambrian time, as allowed under the hot-globe idea, appears too

Physical conditions requisite for at least low forms of life probably were fulfilled when the globe was two thousand miles less than its present diameter. This permits vast length of time for the slow evolvement

[2] The term ''geologic'' is meant to cover only the latter part of the earth's history, or that which is revealed in the observable rock strata. The story is definite and clear for only the unaltered sedimentary rocks, beginning with the Cambrian. Many Precambrian rocks, although much changed (metamorphosed) by pressure, heat, flowage, etc., at great depths, yet indicate formative conditions, by the epigene agencies, not radically unlike the rock formations of recent time.

short to allow the evolution of the Cambrian fauna.	found in the Cambrian of low organisms up to the complex animals strata. That development was at least half of the evolution process from the amoeba to man.
	The origin of life is not within the scope of this writing.

COMMENT

In the above comparison, which is intended to be fair and impartial, the reader will find only one item in which the nebular view might be held superior in its explanation of the earth's features and structure. That is number five, concerning the excessive density of the earth's core. Most of the topics, especially after number eight, are decidedly unfavorable to the nebular view.

HERMAN L. FAIRCHILD

UNIVERSITY OF ROCHESTER

ON THE SIGNIFICANCE OF SCIENCE[1]

Honored Members of the Twelfth Congress on Physiology,

Ladies and Gentlemen:

THE chancellor of the Swedish universities has been prevented by indisposition from being their spokesman on this memorable occasion. Charged with the duties of the chancellor I have been bound to enter into his place. Certainly all of us regret, as much as Dr. Swartz, that he can not realize to-day his keen desire to speak here. We wish him rapid progress in his convalescence. In accordance with his request I transfer to all of you, ladies and gentlemen, his sincere greetings.

Thus it is my most agreeable privilege to express on behalf of the Swedish universities and Swedish research our common joy and pride in receiving in our country so many renowned investigators of the human organism and its functions. To our hearty welcome we add the wish and the hope that your stay in our capital may be fruitful for your high scientific task and pleasant and recreative for each and every one of you.

It was said during and after the world war that if science appeared in the Council of Nations it ought to adorn itself with a bloody vestment, since it served and multiplied destruction everywhere. In large groups of our generation a dire lesson has changed idolatry of science into depreciation of it.

Is science then morally indifferent, so that it can serve death as well as life, the devil as well as God? The problem is not as simple as one might think. In any case there is a moral element in all genuine research. For it belongs to the nobility and sanctity of science to be faithful to its own inmost self. Science must be treated as master, not as servant. It can not without detriment to its purity and success be made ancillary to ready-made dogmatics or wishes. "Naturae non imperatur nisi parendo." It follows its own law. Therefore it requires of the investigator not only labor and perseverance, acuteness of mind and essential imagination, but it requires also self-discipline, subordination of the own ego to higher aims, and conscientiousness and a sincere striving to discover the real connection and character of things and organisms. Therefore, research gives in normal cases to men a stamp of earnestness and truth. A closer investigation will show that deficiency in the moral character must sooner or later have an unfavorable effect on research and its results, at least in important and delicate tasks.

The primitive peoples practice what they call white and black magic, that is sorcery which is used in furtherance of life and sorcery which is used with evil intent. They are right in condemning the latter kind of the primitive science and technic, which we call magic. In the same way modern science must not be used for unworthy purposes. It is a degradation of research to be made subservient to private and collective egoism, to the detriment of mankind.

When science is underrated, one forgets its rôle of furthering life and humanity. During the world catastrophe science exhibited, if possible, still more self-sacrificing zeal and still more genius than ever before, in helping charity to heal and cure, to soothe and comfort. You, gentlemen, are benefactors of humanity, because you represent with honor the art of healing. That redoubles the joy we feel that your international scientific gathering has chosen to meet in the capital of Sweden.

If we consider the relation between science and practical purposes we find a seeming contradiction.

The aim of medical research is practical: to help and strengthen life. Also outside medicine an investigator can be inspired by a conscious practical goal, and that increases his humanity if the goal is good. But the remarkable thing is that the usefulness of science to human life and civilization is not accomplished through any practical aim. It belongs to the secret of science that it serves the practical needs of life best in working with a purely theoretical view. The desire to know carries research out into unknown

[1] Welcome to the Twelfth International Congress of Physiology meeting at Upsala by the pro-chancellor of the University of Upsala and the Archbishop of Upsala.