CLASSICS OF SCIENCE:

Hoover on Ore Deposits

Geology

The translation of Agricola's *De Re Metallica* by President-elect and Mrs. Hoover is doubly a classic of science. The original was one of the great steps in the development of practical geology, but, because it was written in Latin full of technical terms coined by the author, it would have been lost to the present-day world had it not been for the collaboration of the translators. Their scholarship combined with their scientific and technical training and experience made them unique interpreters of the medieval geologist, and their notes on the text are important contributions to the modern literature of geology. They say of Agricola: "In his propositions as to the circulation of ground waters, that ore channels are a subsequent creation to the contained rocks, and that they were filled by deposition from circulating solutions, he enunciated the foundations of our modern theory, and in so doing took a step in advance greater than that of any single subsequent authority." The extract below is from one of Mr. Hoover's notes on the translation. It elaborates his estimate of Agricola's part in the history of mining geology.

Georgius Agricola DE RE METALLICA, translated from the first Latin edition of 1556 *with Biographical Introduction, Annotations and Appendices upon the Development of Mining Methods, Metallurgical Processes, Geology, Mineralogy and Mining Law from the earliest times to the Sixteenth Century by HERBERT CLARK HOOVER . . . and LOU HENRY HOOVER . . . Published for the Translators by The Mining Magazine, Salisbury House, London, E. C.,* 1912.

Historical Note on the Theory of Ore Deposits

Prior to Agricola there were three schools of explanation of the phenomena of ore deposits, the orthodox followers of the Genesis, the Greek Philosophers, and the Alchemists. The geology of the Genesis—the contemporaneous formation of everything—needs no comment other than that for anyone to have proposed an alternative to the dogma of the orthodox during the Middle Ages, required much independence of mind. Of the Greek views—which are meagre enough—that of the Peripatetics greatly dominated thought on natural phenomena down to the seventeenth century. Aristotle's views may be summarized: The elements are earth, water, air, and fire; they are transmutable and never found pure, and are endowed with certain fundamental properties which acted as an "efficient" force upon the material cause—the elements. These properties were dryness and dampness and heat and cold, the latter being active, the former passive. Further, the elements were possessed of weight and lightness, for instance earth was absolutely heavy, fire absolutely light. The active and passive properties existed in binary combinations, one of which is characteristic, *i. e.*, "earth" is cold and dry, water damp and cold, fire hot and dry, air hot and wet; transmutation took place, for instance, by removing the cold from water, when air resulted (really steam), and by removing the dampness from water, when "earth" resulted (really any dissolved substance). The transmutation of the elements in the earth (meaning the globe) produces two "exhalations", the one fiery (probably meaning gases), the other damp (probably meaning steam). The former produces stones, the latter metals. Theophrastus (On Stones, I to VII) elaborates the views of Aristotle on the origin of stones, metals, etc.:."Of "things formed in the earth some "have their origin from water, others "from earth. Water is the basis of "metals, silver, gold, and the rest; " 'earth' of stones, as well the more "precious as the common . . . All "these are formed by solidification of "matter pure and equal in its con-"stituent parts, which has been brought "together in that state by mere afflux "or by means of some kind of perco-"lation, or separated. . . . The solidi-"fication is in some of these substances "due to heat and in others to cold." (Based on Hill's Trans., pp. 3-11). That is, the metals inasmuch as they become liquid when heated must be in a large part water, and, like water, they solidify with cold. Therefore, the "metals are cold and damp". Stones, on the other hand, solidify with heat and do not liquefy, therefore, they are "dry and hot" and partake largely of "earth". This "earth" was something indefinite, but purer and more pristine than common clay. In discussing the ancient beliefs with regard to the origin of deposits, we must not overlook the import of the use of the word "vein" (*vena*) by various ancient authors including Pliny (XXXIII, 21), although he offers no explanation of the term.

A—Descending into the shaft by ladders B—By sitting on a stick. C—By sitting on the dirt. D—Descending by steps cut in the rock.

SIXTEENTH CENTURY METHODS of descending into a mine. From De Re Metallica

During the Middle Ages there arose the horde of Alchemists and Astrologers, a review of the development of whose muddled views is but barren reading. In the main they held more or less to the Peripatetic view, with additions of their own. Geber (13th (?) century . .)pronounced the conception that all metals were composed of varying proportions of "spiritual" sulphur and quicksilver, and to these Albertus Magnus added salt. The Astrologers contributed the idea that the immediate cause of the metals were the various planets. The only work devoted to description of ore deposits prior to Agricola was the *Bergbüchlin* (about 1520), and this little book exhibits the absolute apogee of muddled thought derived from the Peripatetics, the Alchemists, and the Astrologers. . . .

Agricola's Views on the Origin of Ore Deposits

Agricola rejected absolutely the Biblical view which, he says, was the opinion of the vulgar; further, he repudiates the alchemistic and astrological view with great vigor. There can be no doubt, however, that he was greatly influenced by the Peripatetic philosophy. He accepted absolutely the four elements—earth, fire, water, and air, and their "binary" properties, and the theory that every substance had a material cause operated upon by an efficient force. Beyond this he did not go, and a large portion of *De Ortu et Causis* is devoted to disproof of the origin of metals and stones from the Peripatetic "exhalations".

No one should conclude that Agricola's theories are set out with the clarity of Darwin or Lyell. However, the matter is of such importance in the history of the theory of ore deposits, and has been either so ignored or so colored by the preconceptions of narrators, that we consider it justifiable to devote the space necessary to a reproduction of his own statements in *De Ortu et Causis* and other works. Before doing so we believe it will be of (*Turn to next page*)

Hoover on Ore Deposits—*Continued*

service to readers to summarize these views, and in giving quotations from the Author's other works, to group them under special headings, following the outline of his theory given below. His theory was:

(1) Openings in the earth (*canales*) were formed by the erosion of subterranean waters.

(2) These ground waters were due (*a*) to the infiltration of surface waters, rain, river, and sea water; (*b*) to the condensation of steam (*halitus*) arising from the penetration of the surface waters to greater depths—the production of this *halitus* being due to subterranean heat, which in his view was in turn due in the main to burning bitumen (a comprehensive genera which embraced coal).

(3) The filling of these *canales* is composed of "earth", "solidified juices", "stone", metals and "compounds", all deposited from water and "juices" circulating in the *canales*.

"Earth" comprises clay, mud, ochre, marl, and "peculiar earths" generally. The origin of these "earths" was from rocks, due to erosion, transportation, and deposition by water. "Solidified juices" (*succi concreti*) comprised salt, soda, vitriol, bitumen, etc., being generally those substances which he conceived were soluble in and deposited from water. "Stones" comprised precious, semi-precious, and unusual stones, such as quartz, fluor-spar, etc., as distinguished from country rock; the origin of these he attributed in minor proportion to transportation of fragments of rock, but in the main to deposits from ordinary mineral juice and from "stone juice" (*succus lapidescens*). Metals comprised the seven traditional metals; the "compounds" comprised the metallic minerals; and both were due to deposition from juices, the compounds being due to a mixture of juices. The "juices" play the most important part in Agricola's theory. Each substance had its own particular juice, and in his theory every substance had a material and an efficient cause, the first being the juice, the second being heat or cold. Owing to the latter the juices fell into two categories—those solidified by heat (*i. e.,* by evaporation, such as salt), and those solidified by cold (*i. e.,* because metals melt and flow by heat, therefore their solidification was due to cold, and the juice underwent similar treatment). As to the origin of these juices, some were generated by the solution of their own particular substance, but in the main their origin was due to the combination of "dry things", such as "earth", with water, the mixture being heated, and the resultant metals depended upon the proportions of "earth" and water. In some cases we have been inclined to translate *succus* (juice) as "solution", but in other cases it embraced substances to which this would not apply, and we feared implying in the text a chemical understanding not warranted prior to the atomic theory. In order to distinguish between earths (clays, etc.,) the Peripatetic "earth" (a pure element) and the earth (the globe) we have given the two former in quotation marks. There is no doubt some confusion between earth (clays, etc.,) and the Peripatetic "earth", as the latter was a pure substance not found in its pristine form in nature; it is, however, difficult to distinguish between the two. . . .

Conclusion

If we strip his theory of the necessary influence of the state of knowledge of his time, and of his own deep classical learning, we find two propositions original with Agricola, which still today are fundamentals:

(1) That ore channels were of origin subsequent to their containing rocks; (2) that ores were deposited from solutions circulating in these openings. A scientist's work must be judged by the advancement he gave to his science, and with this gauge one can say unhesitatingly that the theory which we have set out above represents a much greater step from what had gone before than that of almost any single observer since. Moreover, apart from any tangible proposition laid down, the deduction of these views from actual observation instead of from fruitless speculation was a contribution to the very foundation of natural science. Agricola was wrong in attributing the creation of ore channels to erosion alone, and it was not until Von Oppel (*Anleitung zur Markscheidekunst,* Dresden, 1749 and other essays), two centuries after Agricola, that the positive proposition that ore channels were due to fissuring was brought forward. Von Oppel, however, in neglecting channels due to erosion (and in this term we include solution) was not altogether sound. Nor was it until late in the eighteenth century that the filling of ore channels by deposition from solutions was generally accepted. In the meantime, Agricola's successors in the study of ore deposits exhibited positive retrogression from the true fundamentals advocated by him. Gesner, Utman, Meier, Lohneys, Barba, Rössler, Becher, Stahl, Henckel, and Zimmerman, all fail to grasp the double essentials. Other writers of this period often enough merely quote Agricola, some not even acknowledging the source, as, for instance, Pryce (*Mineralogia Cornubiensis,* London, 1778) and Williams (Natural History of the Mineral Kingdom, London, 1789). After Von Oppel, the two fundamental principles mentioned were generally accepted, but then arose the complicated and acrimonious discussion of the origin of solutions, and nothing in Agricola's view was so absurd as Werner's contention (*Neue Theorie von der Entstehung der Gänge,* Freiberg, 1791) of the universal chemical deluge which penetrated fissures open at the surface. While it is not the purpose of these notes to pursue the history of these subjects subsequent to the author's time, it is due to him and to the current beliefs as to the history of the theory of ore deposits, to call the attention of students to the perverse representation of Agricola's views by Werner (op. cit.) upon which most writers have apparently relied. Why this author should be . . . so generally considered the father of our modern theory, can only be explained by a general lack of knowledge of the work of previous writers on ore deposition. Not one of the propositions original with Werner still holds good, while his rejection of the origin of solutions within the earth itself halted the march of advance in thought of these subjects for half a century. It is our hope to discuss exhaustively at some future time the development of the history of this, one of the most far-reaching of geologic hypotheses.

Georgius Agricola (1490-1555), whose name was originally Bauer, began his scholarly life at 20 as teacher of Greek at Zwickau, Saxony, but continued studying and eventually mastered physics, chemistry and medicine. At about 35 he located as a physician in the mining region of Joachimsthal. There he observed the mining art in the scientific spirit and described it in a number of books, of which *De Re Metallica* is the most comprehensive. It was written in 1550, but was not published until the year after the author's sudden death—which was brought on by excitement in a dispute on religion.

Herbert Clark Hoover (1874—) and **Lou Henry Hoover,** while living at Red House in London, in the lull between Mr. Hoover's mining career and his war-time service, found time for their translation of *De Re Metallica,* a monumental work of scholarship in mining history. Mr. Hoover's life has fallen into four periods: as mining engineer, to 1914; as Relief and Food Administrator, to 1920; as Secretary of Commerce, to 1928; and as President of the United States, beginning this year.