FORMATIONS AND SCHOOLS OF THOUGHT

Preamble

> John Stuart Mill correctly noted that teacher and learner alike fall asleep at their posts when there is no enemy in the field. —E. O. Wilson.[1]

A *formation* is a mappable unit of rock. What is mapped as a formation will depend on many criteria, the most important of which can be the geologist's philosophy. Two geological schools of thought at the beginning of 19th century were neptunism and plutonism.

a26 What was neptunism? < universal formations >

> Virgil's peasant fondly imagined his native village a miniature of imperial Rome. —Greenough, commenting wyrly on Werner's formations [2]

Abraham Gottlob Werner
His "geognosie" (*geognosy*: Earth knowledge) included what a locale's culture reveals and prospecting finds as to the nature and distribution of minerals in four universal formations. This holistic notion had pragmatic value for deciding where, and when there, for what, to prospect. We are reminded of Francis Bacon's dictum: "Truth emerges more readily from error than from confusion."[4]

Abraham **Werner** (1749-1817) taught that all rocks with a crystalline texture, such as granite and basalt, were precipitated in an orderly sequence from a worldwide primeval ocean.[3] Proponents of Werner's view (which was focused, if not original), and who embellished it, became known as *neptunists*:

> Their inference was that Earth was little older than remembered history. Sun, a burning coal, was yet so bright that its fire could not be old. The Flood, in sooth a reality, had piled up mountains and deposited and buried shells (marine fossils) at high altitude. The mountains, by the shadows they cast, had transformed the region from antediluvian warmth to harsh chill. By the decay of rock, the end of time is foretold. Yet so fresh is the scenery, that Earth is not old.

Werner taught practical mineralogy at the University of Freiberg, Germany. He was also employed as a consultant mining expert. His library was extensive and he was well read. Werner did not travel beyond the borders of his home province of Saxony. While still young he developed a conception of how Earth originated. This conception was in fact just a convenient summary of what he had seen of the geology of the Erz Mountains, where tin was mined, and of what he had read of the regional geology of other mineralogically interesting districts.

The following is a brief description of the origin of formations recognized by Werner. It *should* be read with a jaundiced eye. And, in fairness to Werner, this review is anachronistic as his goal was *not* to formulate a geohistory but to sketch an easy to recall ordering of major geostructural units—which classification proved useful to miners and prospectors of minerals.

In Werner's (false) conception, all oldest rocks originated as crystalline sediments that were chemically precipitated from an initial universal ocean. These, his *Primitive* (English terms introduced by Robert Jameson in *Elements of Geognosy*, 1808)[5] formation rocks are crystallines (granites, gneisses, and schists) composed of the least-soluble minerals. Typically they contain no fossils. The uneven surface of the initial precipitation of the Primitive crystallines formed the main features of the present landscape. As such, the high mountains have always been. The volume of the universal ocean was reduced by the subtraction of Primitive crystallines (a false notion as the volume of water is not changed by salts in solution) and the highest peaks in the landscape became early exposed. Continued precipitation of crystalline materials, thereafter, plastered the mountain slopes

with layers of slate and hard limestone. Intervening with these are steeply inclined layers of detrital sediments, mostly graywakes, derived from higher elevations. Some of the layers are fossiliferous. Permineralization at high elevations, testifies to an often high stand of the then ocean. In some regions, the attitude of the layers suggests the collapse of underground caverns. Then the ocean, in its turbulence, began to oscillate in its level so that the foothill elevations became built of alternating, essentially horizontal, layers of soluble minerals as precipitates and of reworked detrital sediments. Called by the descriptive name *Stratified*, these rocks are typically beds (layers) of massive limestone, shelly limestone, chalk with flint (dark gray to black, conchoidal fracturing, chert) nodules, gypsum, salt, shale, sandstone, coal, and basalt. The ocean finally retreated to its present level and condition. Since then rivers have deposited gravels and muds at times of flood in lowland areas. Coastal, weakly-consolidated marly sandstone, peat, and clay are also of this age. All these youngest sediments are called *Alluvial*. During Alluvial time, volcanism, where it is in evidence, is due to the underground burning of Stratified coals. (A modern example is in Centralia, PA.[6] There, as described by Sid Perkins "the ground is prone to sudden and unexpected collapse. Hot, sulfurous gases waft from vents in the earth, kill trees, drive away wildlife, and sometimes threaten people's lives. Plumes of smoke rise from cracks in a highway that's been closed for more than a decade. This once-bustling town isn't astride the gates of Hell, but instead sits atop an underground coal fire.")[7]

Werner's subdivision of geological time incorporated what was best known in the literature of his day of stratigraphic subdivisions as, in Germany, by Johann Gottlob Lehmann (1719-1761) (a "theory of Earth" scriptural geologist) into Primary (azoic, ore veined rock), Secondary (fossiliferous strata), and alluvials, and, in Italy, by Giovanni Arduino (1714-1795) (whose secular description of geologic complexity may have freed Werner from adherence to a Biblical chronology[8]) into Primary (azoic, ore veined, chaotic strata, molded by fire and later by reactions with water), Secondary (fossiliferous, many-event recording strata), Tertiary (valley-fill sedimentary strata), and volcanic.[9] However, Werner's opinion that, excluding volcanics, all non-detrital crystalline materials had been in solution in water originally, echoed that of Torbern Olof Bergman (1735-1784).

A formation is a mappable unit of rock. That is, at a given scale, the same should be readily recognizable by another geologist. Werner's *Gebirge* (formations) were volumes of rock of mountainous proportions that in various localities had been described by others. In 1787, Werner systematized all these in a pamphlet: *Kurze Klassifikation* (short classification).[10] Formations are distinguished by distinctive mineral assemblages overall or of internal subdivisions and the order of origination. The *Vulkanische* (Volcanic rocks), a separate formation described by others, is incorporated as part of his Alluvial formation. Later he names, in his teachings, but not in print, a new formation: the *Transition*. From oldest to youngest, Werner's *Gebirge* were named using the German adjectives: *uranfängliche* (Primitive), *übergangs* (Transition), *flötz* (Stratified: literally *Flood-deposited*, equivalent to Secondary), and *aufgeschwemmte* (Alluvial: literally *swept-together*).

Werner promoted the concept of universal formations (his *Gebirge*). The ore-bearing crystalline Primitive and ore-poor graywake Transition should be everywhere as he had described. The sequentially younger coal-bearing Stratified and placer-bearing Alluvial formations would be more variable in their composition but their higher and lower altitudes respectively distinguish them. Accordingly, exposed rock type and scenery together allow a region anywhere on Earth to be assigned to one of his formations. Prospection for economically important Earth materials typical of each formation could then proceed in a systematic way by "a science which treats the solid body of the earth as a whole and of the different occurrences of minerals and rocks of which it is composed and of the origin of these and their relations to one another." So empirical Earth knowledge, that is geognosy, would be added to. The word *geognosy* had been coined by Georg Christian Füchsel (1722-1773) in *History of the land and sea based on a history of the Thuringen mountains*, 1762,[11] in which he laid out general principles of (what is now called) *historical geology*, and related the origin of veins and their minerals to dynamic changes in Earth's crust. He had also pioneered stratigraphy by reporting measurements he made of sections of stratified rock and originated the idea of stratigraphic formations by describing nine "types" of strata in Thuringen and Harz mountains.[12]

Given the primitive state of geological knowledge at the beginning of the 19th century, it did not matter that Werner did not correctly identify the true origin of the materials of his formations. The fact that Werner's formations could be recognized was good enough. The geology of England and Wales was initially interpreted in terms of Werner's formations and the relative age of these subdivisions, it so happens, was correct. Such early successes unfortunately perpetuated an overriding enthusiasm for Werner's ideas long after his *geognosy*, as he called his teachings, was shown in almost every detail to be incorrect.

One Wernerian principle that is hard to stamp out is that the age of a rock can be judged from its appearance. This principle is highly misleading except that it is true that sediments younger than 100 million years old are generally only weakly consolidated. After Devon coals were found in "greywacke" (a word and its Wernerian usage introduced in Britain by Robert Jameson in 1808),[13] Roderick Murchinson in 1839 wrote impatiently: "it has already been amply shown that this word should cease to be used in geological nomenclature, ... it is mineralogically worthless." [14]

In Werner's scheme, volcanics rocks (his *Vulkanishe* formation that detractors to his classification of all rocks as sedimentary had required him to recognize) are of minor importance; all being young. They exist, he explained, only as the result of a *coal seam* (miner's term for *coal bed,* i.e. a sedimentary layer of coal) catching alight underground. In this he was wrong but would not have been as to their age had he had referred only to volcanic glasses such as obsidian. Volcanic glasses lack long-range internal crystal ordering and like window glass are highly viscous liquids. However, solid-state diffusion aided by water usually present in volcanic rock allows ions to rearrange and obsidian totally crystallizes over geological time. The crystals that form at low temperature are usually too small to be seen but the devitrified (crystalline) obsidian no longer looks like glass. As a result, true (glassy) obsidians have not been described in volcanics exceeding 20 million years old.[15]

Werner made no attempt to correlate his geohistory with biblical chronology. Others did. Notably, in a eulogy delivered to the *Académie des Sciences* in 1819, Georges Cuvier emphasized what he felt to be unassailable Flood related aspects of Werner's neptunist theory.[16] Followers of Cuvier's ideas became known as catastrophists. ❑

Figure a27.1 **James Hutton** (1726-1797) Hutton's principle of uniformitarianism ran counter to any philosophy that found for a literal interpretation of theological stories of Earth's origin.

Biographical Notes: Hutton was second son of Sarah Balfour and William Hutton (merchant and City Treasurer in Edinburgh, Scotland). Orphaned at a young age, Hutton received his early education in the local grammar school. He and a friend, James Davie, shared a chemistry hobby that led to their discovery and exploitation of an inexpensive method for the manufacture of sal ammoniac (NH_4Cl) from coal soot. Hutton went on to study medicine for three years at the University of Edinburgh and two in Paris. He was granted an M.D. degree, Leyden, Holland, in September 1749. He did not practice medicine as his interest was diverted to husbandry arts and to scientifically improve tillage of two small farms near Slighhouses in Berwickshire, Scotland, inherited from his father's estate at the end of 1750. He geologized widely throughout Britain. In 1768, he retired to Edinburgh where he continued to pursue his scientific interests and to philosophize with a congenial circle of scientifically minded friends. Unmarried, abstemious by habit, he lived with his three sisters in a house he had built in then fashionable St. John's Hill until a brief illness occasioned his death in 1797. An illegitimate student-day dalliance was posthumously revealed when his lineal (via a son) grandson sought help from his friend John Clerk of Eldin.[1]