

## Original meaning of the notion and term “Formation” in geology

ALEKSANDAR GRUBIĆ<sup>1</sup>

**Abstract.** The notion of (geological) formation has gradually developed through mostly German terms: from *ein Gebirge*, which was used by Saxon miners for several centuries (AGRICOLA), then *Schichten*, *Bergart* (LEHMANN) and *serie montana* (FUCHSEL) to *Gebirgsart* (WERNER). The term ‘formation’ was introduced by WERNER in 1791 and its meaning was clearly defined around 1800. He included the notion of “formation” into his system of “geognostic structures”: mineral; rock (layer); formation; Earth’s crust. Therefore, it was an equivocal term from the start. It implied a geological body of certain composition, genesis and superposition (*i.e.* time of origination). After Werner, the term ‘formation’ was used in different ways, mostly as a synonym for a ‘system’, until 1881 when such use was forbidden. The original Wernerian sense of the term ‘formation’ (as a unit in geological levels of organisation: mineral–rock–formation–geosphere–planet) with an intentionally equivocal meaning was not restored until the second half of the twentieth century.

**Key words:** formation, Gebirge, Gebirgsart, serie montana, Fuchsel, Werner.

**Апстракт.** У раду се третирају појам и термин (геолошка) формација према ономе шта су о томе писали Агрикола, Леман, Фухсел и Вернер. Појам се развијао постепено из вишевековне праксе саксонских рудара („en Gebirge“) а термин „формација“ је увео немачки геолог Вернер (A.G. WERNER) 1791. године. Око 1800. године исти аутор је унео формацију у свој систем „геогностичких структура“: „минерал – стена (слој) – формација – земљина кора“. На тај начин термин формација је постао вишезначан. Подразумевао је геолошко тело одређеног састава, постанка и суперпозиционог положаја (односно старости). То је скоро потпуно игнорисано током целог XIX века. Шездесетих година XX века руски геолог Драгунов (1965) дошао је до истог фундаменталног става који је открио Вернер. Писац ових редова се залаже за повратак изворној примени појма и термина формација јер се управо тако превазилазе сва многобројна схватања око којих се деценијама сукобљавају разне школе.

**Кључне речи:** формација, Gebirge, Gebirgsart, serie montana, Fuchsel, Werner.

### Introduction

The *International Guide to Stratigraphic Classification and Terminology* defined the term ‘formation’ as follows:

The Formation is the fundamental formal unit of lithostratigraphic classification ... and is the only formal unit which is used for completely dividing the whole stratigraphic column all over the world into named units on the basis of lithostratigraphic character (HEDBERG 1972, p. 20).

Its hierarchic position within the lithostratigraphic sequence (layer–member–formation–group) was then

precisely specified. However, the original meaning of the term ‘geological formation’ or simply ‘formation’ was not restricted to this definition. It was just one of its aspects, which had reference to geological mapping.

According to its original sense in the eighteenth century (WERNER 1791), but also in the discussions and usage during the second half of the twentieth century, this notion of ‘formation’ acquired a much deeper, broader and more significant sense. Thanks to fruitful discussions among different conflicting schools of geology, it became clear that the term ‘formation’ has a precisely defined position in the ‘geological levels of organisation of matter’, between ‘rock’ and ‘geosphere’ (DRAGUNOV 1968; KRUT

<sup>1</sup> University of Belgrade, Faculty of Mining and Geology, Department of Historical and Dynamic Geology, Kamenička 6, 11000 Beograd, Serbia

1968). This fact paved the way for an awareness that establishing of ‘formational geology’, *i.e.* of a group of geological disciplines essentially based on the study, identification and use of formations was taking place (GRUBIĆ 1985).

In modern geology, ‘formation’ is one of the fundamental geological notions, because it lies at the base of the whole of applied geology as well as a large part of theoretical geology. It is particularly important to emphasise that knowledge of geological formations is of vital importance for the exploration of mineral ore deposits, engineering geology, hydrogeology, and environmental protection.

Moreover, the application of ‘formational analysis’ in the production of ‘geologic’ maps of the Moon and Mars by means of remote sensing showed that formations, as well as minerals and rocks, are not only terrestrial but also cosmic entities, causally related to the evolution of terrestrial-type planets.

Such significance of the notion and term ‘formation’ in the family of Earth Sciences suggests a need to study, reconstruct and precisely define its historical roots, since there are inconsistent citations and usages in the literature.

### Saxon miners and Georg Agricola

German miners started quite early to use the geographical term *Gebirge* (mountains) for the geological space “below the surface of the Earth, [regardless of whether] whether the surface [wa]s mountainous or plain” (OSPOVAT 1999, p. 14). In other words, the term was the close to the modern concept of ‘the underground’ in its material sense. Since during their complicated and arduous work Saxon miners ran into alternations of rocks in which they used different tools and techniques, they began to distinguish thick and thin sequences of rocks with similar characteristics. For thick sequences, they used the term *Gebirge*, which was always related to a characteristic feature of an actual rock sequence (*e.g.* *das blaue Kohlen-Gebirge*: LEHMAN 1756, p. 167). Sequences of medium and small thickness were called *Lage(r)* and *Schicht* respectively. The term *Floetz* was used for a ‘layer’ in a narrower sense. All these were important elements of mining organisation.

Such professional terminology in the mines of Thuringia was recorded by AGRICOLA (1521, p. 96) in his description of “the roof of the copper schists of Mansfield”. Among the other rocks, he referred to the following *Gesteinsschichten* (rock layers): “First, 20 to 35 *Lachter* of dark red *Gebirge* ... ; Second, 1 *Lachter* of gray-clay *Floetz* ...; ash-gray rock with 3 *Lachter* of ... ash and 5 *Lachter* of rock fragments”. (*Lachter*: an old German unit of length, used in mining industries. It varied somewhat from one region to the next but was approximately two metres in length).

At the time when Agricola obtained the above mentioned data from mine workers, they were still distinguishing rock sequences according to their color and work techniques they used. This lasted for two more centuries.

In the eighteenth century, miners in Thuringia already knew different rock types, thus they could identify different rock sequences and name them according to the main rock. Color of the rock became a secondary characteristic, but superposition of each sequence became very important. This was based on the fact that the order of thin and thick sequences of layers in almost undisturbed sediments of Thuringia was constant and well known to the miners. This is also the answer to the question: why the Saxon miners in Thuringia were the first to clearly distinguish alternations of sequences made up of different rocks in vertical succession.

### Johann Gottlob Lehmann

The oral tradition of Saxon miners was accepted by J. G. LEHMANN, a mining inspector with an excellent mining and geological education and experience and a good knowledge of geological literature. With his mining experience, Lehmann knew that there was a succession of different rocks in the Earth’s crust and that it was constant in Thuringia. He also used his experience of studying the surface outcrops of the rock layers of the region. He knew, however, that this idea had not been developed and described in detail. So he decided to take this task as his ‘minor’ contribution (LEHMANN 1756, ‘Preface’).

In his well-known monograph about the area between Ilfeld and Mansfield counties in Saxony, LEHMANN (1756) described the rock succession in detail and represented it in a well-known cross-section (LEHMANN 1756, Table 7, p. 162). He distinguished thirty-one units: ten thicker and the rest thinner. Each unit received a precisely defined position in the vertical succession, as well as the specific characteristics and name used in mining terminology. He used a general term *Schichten* for all these units (p. 162). In general, Lehmann did not use the term *Gebirge* (because of its very specific meaning, referring to the underground) in his name for each unit. However, he included *Gebirge* in the names of three of the units – in sequences 19, (*felsige Gebirge*), 23 (*leberfarbene Gebirge*), and 24 (*blaue Kohlen-Gebirge*). He used the term *Floetz* for actual layers. It is interesting that he used that term only once for a whole unit (No. 29), but he also used it for all sedimentary rocks of Thuringia: *Floetz-Gebirgen* (p. 157). Thus Lehmann often used the term *Schichten*, but only rarely *Gebirge*, for recognisable sequence made up of identical or similar rocks. He also used also the term *Bergart* on one occasion for the rocks in Unit 28 (p. 168). This was another mining term that would later be used by WERNER.

Several important conclusions can be drawn from Lehmann’s book. In the first place, he introduced into the professional literature an idea from mining practice in Thuringia—that there are recognisable large geological bodies in the Earth’s crust made up of the same rocks and minerals. Lehmann also assigned a particular (mining) name to each of the established rock units. Furthermore, he occasionally used the old mining term for ‘underground’ (*Gebirge*), but did not use it consistently in the names of these bodies because he knew it had a specific meaning in mining terminology. Finally, he mostly used term *Schichten* (i.e. ‘layers’) for the bodies that he mentioned. He used the name *ein Floetz* (i.e. ‘one layer’) for only one of his units (No. 29, p. 168), in order to make a distinction between the larger and smaller units within the named unit.

In this way, the practical mining terms for distinguishing and naming large subsurface geological bodies recognizable by their composition, was also applied in Lehmann’s book to the surface outcrops and thereby was introduced into the geological scientific theory and literature. But a specific term was not assigned to these bodies. He used the terms *Schichten*, *Gebirge* and *Bergart* instead.

## Georg Christian Fuchsel

Several years after the Lehmann’s book, GEORG CHRISTIAN FUCHSEL (1761) published his famous *Historia terrae et maris ex historia Thuringiae, per montium descriptionem* in Latin. (Fuchsel published his book under his Latinised name, which is therefore used here, rather than the more usual spelling.) Fuchsel was a well-educated doctor, an outstanding naturalist and connoisseur of the specialised literature of his time, as is confirmed by the variety of subjects on which he wrote extensively. Besides having an intimate knowledge of Lehmann’s work, he was also a skilled field observer and Lehmann’s book encouraged him to publish everything that he discovered during his several years of field investigations and sampling in the area of Thuringia southwest of Jena. His original idea of delineating the superficial extent of geological units—which had otherwise been known only to miners and Lehmann—on a rough sketch of the region was particularly important. This was how this very early geologic map in the world originated (FUCHSEL 1761, Tab. V). The author needed a more precise identification of large geological bodies with distinctive characteristics. This demanded several years of systematic, persistent and thorough fieldwork, an inventive mind and original solutions in synthesizing the large amount of collected data, because Fuchsel had no pattern to follow.

Fuchsel’s text was comprised of two parts (*sectio*). The first, shorter part had eighty-one pages of theoret-

ical discussion and a short description of the units that he established, while the his interpretation of the geological history of Thuringia was presented in about hundred pages in Part 2. The whole was accompanied by tables and illustrations.

Following the mining practice, Fuchsel theoretically separated and precisely defined three types of units (pp. 46–48): *stratis* (*Schichten*); *serie montana* (*ein Gebirge*); and *serie statuminis* (*ein Unterlager*). Unlike Lehmann, he followed the mining terminology strictly, but in order to avoid possible confusion, he chose not to use the word *Floetz* (layer) as much as possible.

Fuchsel’s text was published in Latin, but he kept the corresponding German names in brackets for all the important terms. This is important for a proper understanding of Fuchsel’s procedures and the terminology that he applied. If he had not done it that way, one would have hardly realised that the old German term *ein Gebirge* was hidden behind *serie montana*! One should pay attention to the fact that the author did not simply use the word *Gebirge* for a geological body. Rather, he wrote *ein Gebirge* thus emphasising that it was just “one part of the underground”.

We may leave aside here the term *stratus*, because it simply meant a single material layer. But it is necessary to discuss the terms *serie montana* and *serie statuminis*.

Fuchsel gave two complementary definitions of *vero series montanas* (p. 50) or simply *serie*. In the first definition (Paragraph 4, p. 48), he wrote: “Mountains made up of identical deposits (*situs*), with the same composition (*massa*) and of the same origin (*modo constructos*) c[an] be named *serie montana* (*ein Gebirge*)”. In the second definition in Paragraph 45 (p. 9), he wrote: “*Serie montana* are thick layers composed of numerous thinner layers”. According to these definitions and the attached map—a kind of block diagram for the area studied—it is clear that when Fuchsel used the phrase *serie montana* he was referring to geological bodies of large dimensions, large enough to be distinguished, separated and represented on his map. Therefore, the idea ‘mapped unit’—a fundamental concept in contemporary geological mapping—was born.

Fuchsel did not give a strict definition of the term *serie statuminis*. However, according to the description in Paragraph 5 (p. 48) and the corresponding German word (*ein Unterlager*), it appears that it can be construed as “a sequence of thin layers” that mutually alternate (*Wechsel*). These layers lie between two *serie montana* from which they differ, connecting them and separating them, with the lower one making the footwall of the upper one.

Applying these notions, Fuchsel separated and described nine *serie montana* that always had the mining suffix *-gebirge* in the German names (e.g., *oberste Kalchgebirge*, *rothe Schalgebirge*, etc.) and six *statu-*

*minis* that contained *Lager* in their names (*rothe tode Lager, etc.*) in the area that he studied southwest of Jena. The word *Floetz* was used only once (Unit 17e, *Sandfloetz*, p. 62). All these units were designated by numbers (10 to 25) on the map and by letters (A to K) on the diagrams.

Because of the need to graphically present the extent of each *serie montana*, Fuchsel understood that the positions of lithologic units in the vertical sequence of rocks and in geographical space are very important for its occurrence on the surface. This was further emphasised by the presentation of the established units on a primitive block diagram (in the accompanying tables). Thus, he made every effort to explain the terms: *situs* (*Lager*) and *positus* (*Stand*). The first term related to the superpositional relationships between any given unit and the other units, while the other term referred to the position of a unit in the geographical space.

By this work, Fuchsel set the foundations for future formational analysis. In his area of study, he defined, separated and mapped geological bodies that we accept as distinct formations today. He emphasised the importance of ‘mass’ (composition), position, distinctiveness and fossil content for their distinguishing and separation. He thought that each such body should be given a particular name (p. 48). And he clearly distinguished *vero series montanas* from *serie statuminis*, which means ‘formations’ and ‘layers’ as particular, objectively separable lithostratigraphic units in their contemporary sense.

All this was really unexpectedly much work for an author from the eighteenth century. Therefore it is unsurprising that Fuchsel’s work is still regularly cited today. The problem is, however, that despite numerous citations, only a small number of experts have had Fuchsel’s work in their hands, which is perhaps why different things have been attributed to him. He did much and introduced several important notions into geological science. But he never used the term ‘formation’, though numerous authors still say otherwise in their texts, starting from KEFERSTEIN (1840, pp. 56–57) and particularly after ZITTEL (1899, p. 51).

### Abraham Gottlob Werner

The term ‘formation’ was introduced into the geological literature by ABRAHAM GOTTLÖB WERNER (1791)—the well-known mining inspector and professor of mineralogy and geognosy at the Freiberg Mining Academy. In order to explain mining to future mining engineers, Werner based his lectures on established mining practices, referring among other things to Lehmann’s book and Fuchsel’s work. The principal terms in these sources were: *Gebirge*, *Schicht*, *Lager*, *Floetze*, and *Bergart*. Werner accepted them, as research subjects, and established the basis for a new

science, which he adumbrated in 1778 and introduced in a new set of lectures under the name *Gebirgslehre* (GUNTAU 1984, p. 67). In addition to the aforementioned terms, Werner used a new one, *Gebirgsart* (‘mountain rock’, as translated by JAMESON: 1812, p. 192), which had not been used previously in the published literature. Actually, Werner used the terms *Bergart* and *Gebirgsart* as synonyms, which can be described in free translation as “a type of underground solid rock” (WERNER, 1817/1818, p. 10, Articles 20 and 22). A trace of all this is to be found in WERNER’S famous work on the classification of *Gebirgsarten* (1787).

Werner considered the terms *Gebirge* and *Gebirgsart* to be of crucial importance at that time. That is why it is interesting to discuss how he used these terms.

At first sight, when reading Werner’s texts informatively, one gets an impression that he used terms *Gebirge* and *Gebirgsart* inconsistently: from using *Gebirge* as a term for the whole underground (or the Earth’s crust), similarly to Saxon miners (OSPOVAT 1999, pp. 14 and 15); and then using both terms as synonyms for *Gestein* (rock) and *Gesteinsart* (rock type) (see GUNTAU 1984, pp. 40 and 80), in cases where a part of the *Gebirge* is made up of one or several *Gebirgsarten* (WERNER 1787, p. 5).

This, however, is just a superficial impression. Werner’s system, to which he held consistently, was quite simple. The Earth crust (*Gebirge*) is made up of actual *Gebirges* that could be simple or composite. The simple *Gebirges* are made up of a single *Gebirgsart*, while the complex ones are composed of two or several *Gebirgsarten*. Moreover, a *Gebirgsart* (*i.e.* *Bergart*) itself could be simple or composite. A simple *Gebirgsart* is made up of a single *Gesteinsart* while two or more of them make a composite *Gebirgsart*. That is all. Such a system allows for a simple *Gebirgsart*, for instance, or even one *Gesteinsart* to be synonyms for simple actual *Gebirge*. This explains an apparent inconsistency in the Werner’s lectures. It is important, however, to understand what he wanted to achieve by using the term *Gebirgsart*. Apparently, the answer to that question is: *Gebirge* is a general term for underground that could be made up of one or several different *Gebirgsarten*.

Miners had three criteria according to which they identified different *Gebirgsarten* in a *Gebirge*: technical work methods in a rock unit, its dimensions (particularly thickness) and its position, *i.e.* its place in the order of superposition (OSPOVAT 1999, p. 15). Besides, Werner had in mind the same criteria but he significantly extended the scope of ‘methods of work’ and replaced them by petrographic characteristics of rocks in the *Gebirgsart*. He clearly emphasised this in his idea that a *Gebirgsart* comprises one or more *Gesteinsarten* (1787, p. 6). According to all this, the term *Gebirgsart* in Werner’s texts referred to a solid

geological body of large dimensions, and with a certain order of superposition and petrographic composition. According to its content, therefore, *Gebirgsart* came close to the future meaning of *Formazion*.

During the first fifteen years of his professorship, Werner, as one conversant with mining, principally focused on mining terminology. However, he did not wholly understand Fuchsel, even though he had his work in his hands. This is confirmed by the fact that Fuchsel's text still exists in the Werner's private library in Freiberg, as well as by his adopting Fuchsel's term 'geognosy' in 1786.

In his system, WERNER (1787) distinguished *Hauptgebirgsarten* (p. 26), including *Hauptarten* (p. 6) and *untergeordnete Bergarten* (p. 11). He systematized the related *Gebirgsarten* into *Gattungen Gebirgsarten* (pp. 16, 21 and 26) and, finally, he divided all deposits that originated during the Earth's history into the following four: *Hauptabtheilungen: uranfängliche-, Floetz-, vulkanische-, und aufgeschwemmte Gebirgsarten* (p. 5).

Therefore, during the first fifteen years of his academic career, Werner used the term *Gebirgsart* for the notions that Lehmann named *Schichten* and *Gebirge*, while Fuchsel used the expressions *serie montana* or *eine Gebirge*. However, Werner used this term in a precisely defined way and incorporated it into the foundation of his classification of geological bodies.

A new period in the development of these issues began with publishing of Werner's famous book on the origination of veins in 1791, in which he used the term *Formazion* (formation) for the first time in print. It had been used before among geologists, but without have any particular geognostic meaning.

In this book, Werner wrote: “I call all the veins of common origin, which might occur together or close to each other in an area, or are far from each other in the different countries, a *Gang-Formazion* or in brief a *Formazion* (1791, pp. 5–6). And he added: “the identity or equivalence of *Gang-Formazionen* ... is recognised and confirmed by comparison of ore types in veins; thus the veins that contain the same types of ore and particularly these composed of several ore types of the same age can be considered as belonging to the same *Formazion*” (1791, p. 54). At the same time, and right from the start, Werner distinguished the *Haupt-Formazionen* of ores and rocks (*sic*) from *Spezielle Gang-Formazionen*. The first term referred to the formations that originate over a long period of time by renewal, while the others are just parts of the *Haupt-Gang Formazionen* of some specific age.

The whole idea of *Gang-Formazionen* is still somewhat unclear, because there are only a few notes that clarify what Werner meant under the term 'formation'. Thus right from the beginning we find: veins of the same origin (p. 5), of the same composition (p. 32), and of the same age (p. 32), for veins filling former fractures.

Thus the term 'formation' was introduced into geological literature for a notion that had already been known in Germany as: *Schichten*, *seriae montana* and *eine Gebirge*. It seems that this also applied to the terms *Bergart* and *Gebirgsart*. This is not specifically mentioned anywhere, but the two words were almost completely abandoned after the use of the term 'formation' began. (But Werner used them again in one of his last texts 1817/1818.)

The next step in introducing the term 'formation' was made by Werner in his manuscript 'Plan of study for geognosy from 11 March 1794', held at the archives of Freiberg University. In chapters on different types of *Gebirge*, there are two conspicuous units that refer to *Gebirgsformazionen* and *Metallformazionen* in the Chapter 13 on the distribution of mineral ore deposits (= *Fossilien*) (from SCHMIDT 1999, p. 156). It means that the term 'formation' was still not completely distinguished from *Gebirge* in 1794. This happened, however, during the next few years because, after 1800, Werner's students published books and articles with quotations of his precise definitions and comprehensive knowledge of formations.

Werner's ideas about formations after 1784 can only be traced in the preserved concepts of his lectures and in the published students' notes (GUNTAU 1984, p. 69). He gave his lectures at the Academy according to his current beliefs so that with his constant effort to express himself as precisely as possible there were continuous changes in and development of his lectures. Werner was aware that his terminology was unstable at that time, so he did not publish anything about geognosy at that time, because he knew that anything he wrote would become obsolete. Just in case, however, he systematically corrected his students' notes, thereby actually authorising the reproduction of his lectures in accordance with his contemporary views. He expected that his students would publish their notes after graduation—and he was right. Many did publish the acquired knowledge in their papers and books, though always referring to their professor. When using these texts, however, it is necessary to keep in mind that the authors might have changed the original notes to a greater or lesser extent, so that they do not always fully correspond to the Werner's ideas. That is why one should rely on the authors who specifically stated that they tried to be faithful to what Werner had said in his lectures.

Sudden improvements of knowledge or ideas about formations were not completely accidental. Werner quickly realised the advantages of the term *Formazion* over older terms that were burdened by traditional and deep-rooted mining notions. Earlier and previously imprecise or ambiguous meanings of the new term could have been modified according to the new geognostic needs of the time. Besides, preparations for the systematic geological mapping of Saxony began in 1791. For that reason, Werner had to prepare a special

instruction manual for fieldwork, which was the main agenda for his students and the other numerous participants in this project between 1798 and 1811. This could not have been carried out without a thorough knowledge of the Fuchsel's work. At that time, Werner's was the only instruction manual that contained extensive practical information for the extensive cartographic work. Through that important preparatory work for geological mapping, methodical studying of Fuchsel's results, and the practical experiences of the first geological mappers, Werner came to realise the vital importance of the term 'formation' for *Geognosia*. Therefore, he decided to replace the term *Gebirgsart* by *Formazion*. He tried to define it as precisely as possible and, finally, to develop a theoretical base for its application.

While discussing the terms *Formazion* and *Gebirge*, Werner wrote that they "relate[d] to each other as a genus to an individual. A *Gebirge* [wa]s a local occurrence of a large rock mass with great horizontal and vertical extent, with uniform characteristics of composition and stratification. All the existing *Gebirgen* with identical characteristics ma[d]e up a *Formazion*" (from GUNTAU 1984, p. 80).

Werner used also the term *Gebirgsformazion* in that phase of his work. According to OSPOVAT (1999, p. 15), he regarded it as: "a determinate assemblage of similar or dissimilar rock masses, which are characterised by external and internal relations as an independent whole, that is, as a unit in a series of rock formations ... and which are recognisable by the characters which each period and mode of formation has impressed upon it". An identical definition was given by ROBERT JAMESON (1808, p. 59) from one of Werner's lectures in 1801, and by FRIEDRICH MOHS in 1842 (PUSCH 1826, p. 524). A similar, but somewhat shorter, definition was published by J. F. AUBUISSON DE VOISINS (1828, p. 268), from a lecture of 1805. Therefore, it is undoubtedly Werner's definition.

According to the published notes of JAMESON (1808, 1813), AUBUISSON DE VOISINS (1828) and others, Werner had a well-developed theory of geological formations after 1800. The theory contained the following general synthesised concepts and solutions.

Werner determined the precise position of a formation in the sequence of the objects that constitute the subject of geognosy: minerals, rocks, layers, formations, and the Earth's crust. At the same time, he distinguished four levels of 'geognostic structures': the structure of rocks (*Gebirgsenstein*); of masses or mineral layers (*Gebirgsmasse*); of formations (*Gebirge*); and of the Earth itself (*Structur der Erde*) (AUBUISSON DE VOISINS 1828, pp. 267–269). But Werner's explanation became completely forgotten and was only discovered again in the sixties of the twentieth century, during the developing of the modern concept of the "geological levels of the organisation of matter" (DRAGUNOV 1965, p. 64; KRUT 1968).

The internal structure of formations could be either simple or compound. A formation is simple when it is comprised of identical material, while a compound formation is made up of different *Lagern*, *couches*, or *rock-masses*. According to their participation in a formation, these could be: principal, subordinate, common (*habituelles*) or accidental (*accidentelles*) (JAMESON 1808, pp. 59–60; AUBUISSON DE VOISINS 1828, pp. 317–318).

Werner thought that formations could occur not only in sedimentary, but also in crystalline rocks (JAMESON 1812, p. 60; PUSCH 1826, p. 514). This was an important point: there are still disagreements among geologists regarding this issue.

But Werner used the term *Formazion* ambiguously. He knew that the notion of 'formation', as with terms for all other natural bodies (mineral, rock, layers, Earth, etc.), involved several different aspects. There were three main aspects of each such natural body: its material composition, as well as the manner and time of its origin. Werner had this in mind from the start (PUSCH 1826, pp. 512–513). But owing to the incomplete knowledge of, misunderstandings of, and unilateral interpretations of Werner's ideas, this important fact has become a source of much discussion and division among researchers and commentators.

Relying on his Neptunist doctrine of the Earth's history, Werner thought that all formations originated by deposition from water. Changes in the water's properties over time resulted in changes in the conditions of deposition, and hence in the conditions for the origin of formations. Formations, therefore, differed in the nature, texture, and generality and also the nature of their petrifications. Crystalline formations are the oldest. Sedimentary formations are in the middle. The youngest are of mechanical origin. (For this paragraph, see: AUBUISSON DE VOISINS (1828, pp. 326, 352, 357).)

According to their material composition, Werner divided formations into: schistose, calcareous, traps, porphyritic, gypseous, coaly, talky, topaz-bearing and schorl. All these formations were classified into four *Hauptgruppen* or *Formazionszeit-raum* (time-space) groups that occur naturally in the form of: *Urgebirge*, *Uebergangsgebirge*, *Floetzgebirge*, *Aufgeschwemte Gebirge* and *Vulkanische Gebirge* (STEFFENS [1801], according to REUSS (1805 pp. 169–184 and *Tabelle* by KARSTEN, p. 185).

Two main categories of formations were distinguished: *universal* or general, which occur on the whole Earth or over its large parts of it; and partial, anomalous or local, which are of limited extent (JAMESON 1812, p. 63; AUBUISSON DE VOISINS 1828, pp. 320–322).

Werner emphasised that formations and their parts contain different fossils. He wrote that: "It is important that different layers in *Floetzkalkgebirgen* contain different petrifications (GUNTAU 1984, p. 89). In his

last published work, WERNER (1817/1818, p. 10) emphasized that even different petrifications form certain *Gebirgsschichten*, which enable us to recognize “a certain order in geological deposits”.

Werner noticed that similar *Gestein-Massen* occurred quite often at different times. Each individual occurrence was a particular formation and the whole was named a *Formazions-Suite* (MOHS 1805, from PUSCH 1826, p. 524). There were said to be two types of *Suiten*: continuous and discontinuous. The first were characterized by the fact that “deposits from different epochs ... change into each other gradually; thus there are no clear boundaries between them”. The others occur in the form of separate and independent bodies. Two distinctive examples were: the ‘schist suite’ and ‘limestone suite’ (AUBUISSON DE VOISINS 1828, pp. 380–383).

Finally, the following formations were distinguished in the Earth’s crust according to the frequency of occurrence: *Haupt-Formazionen* (principal), *Formazion Suiten*—or independent formations and subordinate formations (JAMESON 1808, pp. 60–61; MOHS 1805, from PUSCH 1826, p. 525).

That is how Werner slowly and gradually developed, improved and established a comprehensive knowledge and explanation of geological formations, devoting himself to the tasks of improvement and clarification. One must acknowledge that this work was done most successfully—even masterfully. It is completely understandable, and justifiable, that professor Werner enjoyed a great reputation in his day.

## After Werner

At the age of fifty, Werner was still active when his former students started to publish notes from his lectures. In addition, according to KEFERSTEIN (1840, p. 68):

The notebooks in which Werner’s students were keeping notes at his lectures on geognosy have reached many hands; these notebooks were quickly published, either original, abridged or extended, thus numerous textbooks and manuals appeared and Werner’s doctrine has become more popular in years.

The notes were also published by geologists who did not attend Werner’s lectures directly. And such books became the only published sources of information on *Gebirgs-Formazionen*.

However, the authors of these books soon began to differ in their ideas about formations. This happened in part because Werner himself kept changing and supplementing his lectures and partly because the authors developed different views according to their own ideas and practical experience. Thus some devia-

tions from Werner’s ideas developed, though they were often insignificant. For example, when Werner was still using the term *Gebirgsarten* it was used in the same way by HUMBOLDT (1792) and BOEHMER (1794). But they were also using the term *Formazion* for all rocks of the same petrographic composition (FRANKE 1962, p. 209).

HEIM (1798) was one of the first to draw attention to the ambiguity of Werner’s term ‘formation’. Heim believed that the word should *not* be understood to imply time of origin or relative age. And there were others who had similar ideas about how the expression *Gebirgs-formazion* should be construed—such as MOHS (1805), REUSS (1805), STEFFENS (1810), REICHTZER (1812), and others. On the other hand, KEFERSTEIN (1821), and later HUMBOLDT (1823), AUBUISSON DE VOISINS (1828) and others, maintained that the term ‘formation’ should only refer to the time of a rock or stratum’s origin (FRANKE 1962, pp. 209–210).

The most important and famous among the various critical reviews of Werner’s ideas was that systematically written by GEORG GOTTLIEB PUSCH (1826), who was a student of WERNER in 1806. Pusch correctly noted that Werner’s term *Formazion* meant at the same time rock type, manner of origin, and time of formation (pp. 512–513). In addition, Pusch critically analysed papers written by various authors with different views as to the meaning of this term (Steffens, Mohs, Humbolt, Heim, Breislack, Raumer). Finally, he concluded (pp. 519 and 580) that the term *Formazion* could simply imply time of origination, *i.e.* age. Pusch gave reasons for his conclusion and asserted that this “correct idea” was advocated by the majority of French and German geologists at that time.

Therefore, owing to the fact that geologists, even those who were Werner’s students, did not understand that the term *Formazion*, as used by Werner himself, was *intentionally* ambiguous. So the term deviated from its original meaning during the course of the nineteenth century and it was used more and more in chronostratigraphy as a synonym for ‘system’.

However, it is important to note that, in his *Manuel of Elementary Geology* LYELL (1855, p. 3) advocated the Wernerian notion of ‘formations’ as: “any assemblage of rocks which have some character in common, whether of origin, age, or composition. Thus we speak of stratified and unstratified, freshwater and marine, aqueous and volcanic, ancient and modern, metalliferous and non-metalliferous formations”. This statement was repeated in Lyell’s *Student’s Elements of Geology* (1874). But despite his authority, Lyell was not followed on this point. For example, this part of Lyell’s text was omitted by John Judd’s account of Lyell’s thinking in *The Student’s Lyell* (1896).

After significant disagreements and discussions among the different conflicting geological schools, the original meaning of this fundamental term was

only revived in the second half of the twentieth century, based on the concepts of the “elementarity of natural objects” and “levels of organisation of matter” (DRAGUNOV 1965 p. 64).

## Conclusions

1. The notion of (geological) ‘formation’ developed from an old German mining term *ein Gebirge* (AGRICOLA 1556), through *Schichten* and *Bergart* (LEHMAN 1756), *serie montana* (FUCHSEL 1761), and *Gebirgsart* (WERNER 1787).

2. The term ‘formation’ was introduced into geological literature by WERNER in 1791 to refer to a particular concept.

3. Werner defined a ‘formation’ as “a determinate assemblage of similar or dissimilar rock masses, which are characterised by external and internal relations as an independent whole, that is, as a unit in a series of rock formations ... which are recognisable by the characters which each period and mode of formation has impressed upon it” (OSPOVAT 1999, p. 15). He distinguished formations according to their composition, extent, and frequency of occurrence.

4. Werner considered the term ‘formation’ to refer to a body in the sequence of natural ‘geognostic structures’: mineral–rock (layer)–formation–Earth’s crust. Therefore, the term ‘formation’ in reference to a natural body could have, and *should* have, been ambiguous from the beginning. It embraced: petrographic composition, mode, and time of origin.

5. Werner’s students and followers mostly did not understand the *intentional* ambiguity of the term ‘formation’. They thought that there had been a serious mistake, criticised it, and took different positions in relation to the issue.

6. The interpretation that ‘formation’ could have only one—what we would today call chronostratigraphic—meaning prevailed during the nineteenth century. The term ‘formation’ thus became in effect a synonym for ‘system’. It was widely used in this way until the II International Geological Congress in Bologna in 1881. But despite the ‘prohibition’ on this use of the term ‘formation’, it continued to be used instead of ‘system’ in certain geological schools well into the twentieth century.

7. It is interesting that LYELL (1885, 1874) supported Werner’s idea, even when almost everyone else abandoned it.

8. In the second half of the twentieth century, after all these vicissitudes, the term ‘formation’ regained its original Wernerian sense with the original ambiguity and status of an elementary unit in geological levels of organisation of matter: mineral–rock–formation–geosphere–planet (DRAGUNOV, 1965). Each preceding unit in this sequence is elementary relative to the following one of higher level in this organisation. The

term ‘formation’ is nowadays the main subject of research in ‘Formational Geology’.

## Acknowledgments

Collecting and study of the copies of the original publications cited in this text lasted a long time. Author received kind help from numerous persons and institutions. Some more and some less, but all of them need to receive kind recognition. It is, however, necessary to underline help from: Professor M. GUNTAU (Rostock), and W. LANGER (Germany) and Dr A. SEIFERT (Freiberg) former Director of VEB Geologische Forschung und Erkundung (Freiberg); the National Library in Paris; and Cambridge University Library. The author wishes to express his thanks to Professor DAVID OLDROYD (Sidney, Australia) for his help and remarks in the final version of the manuscript.

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- Blaue Kohlen-Gebirge** – blue (mountain ranges) beds with coal; the twenty-fourth unit in Lehman's cross section of the layered mountain range of Thuringia.
- Ein Gebirge** – one part of (mountain ranges) rocks (= formation).
- Festige Gebirge** – solid (mountain ranges) rocks.
- Floetz** – layer of, or with, non-metallic mineral content.
- Floetz Gebirge** – bedded (mountain ranges) rocks with non-metallic content; the third unit of Neptunist general stratigraphy; the bedded mountain range of Thuringia
- Formazion Suiten** – continual and discontinual recurrences of formations in vertical succession.
- Formazionszeit-raum** – the unity of space and time during the creation of a formation.
- Gang – Fomazion** – (ore) veins of similar composition, origin and age, from one or different areas.
- Gattungen Gebirgsarten** – (mountain ranges) rocks classified in genera according to the prevailing rocks (for example, the genus or real volcanic and genus of pseudo-volcanic mountain ranges rocks).
- Gebirge** – before 1798: mountains; mountain ranges; a general name for all underground rocks; the whole solid crust of the Earth. After 1798: the local development of a larger formation.
- Gebirgsart** – sufficiently large and clearly distinctive (mountain ranges or rock bodies; (= formation).
- Gebirgsformazion** – synonym of ‘formation’.
- Gebirgslehre** – knowledge of the Earth: rocks, different bodies, mineral deposits, dynamics and history; (= geognosy).
- Gebirgs geschichten** – mountain ranges strata.
- Gebirgs gestein** – rock made up simple *Gebirgsart*.
- Gebirgs masse** – general term for any (mountain ranges) rock mass.
- Gestein** – rock.
- Gesteinsart** – rock species.
- Gesteinsschichten** – rock beds, strata.
- Hauptarten** – synonym of *Hauptabteilungen Gebirgsarten*.
- Hauptabteilungen Gebirgsarten** – name of the units of general Neptunist stratigraphy.
- Haupt Gang Formazionen** – vein formations that are long term repeating in succession.
- Hauptgruppen** – synonym of *Hauptabteilungen Gebirgsarten*.
- Hauptgebirgsarten** – universal or principal (mountain ranges) rocks wide spread in the world.
- Hauptformazionen** – synonym of *Hauptgebirgsarten*.
- Lage(r)** – layer.
- Leberfarbene Gebirge** – liver-coloured (mountain ranges) beds; twenty-fourth unit in Lehman's cross-section of the bedded mountain range of Thuringia.
- Lehre von Gebirgen** – synonym of *Gebirgslehre*.
- Metallformazionen** – metalliferous formations.
- Oberste Kalckgebirge** – upper limestone (mountain ranges) beds; youngest *serie* in Fuchsel's stratigraphy of Thuringia (= *Muschelkalk*).
- Rothe Schalgebirge** – red laminated (mountain ranges) beds; sixth *serie* in Fuchsel's stratigraphy of Thuringia.

## Glossary

- Aufgeschwemmten Gebirge** – loose detrital rocks; the fourth unit of Neptunist general stratigraphy.
- Bergart** – synonym of *Gebirgsart* and *ein Gebirge*; (= formation).

**Rothe Tode Lager** – literally ‘red dead layer’; thirtieth unit in Lehmann’s cross-section of the Bedded mountain range of Thuringia.

**Sandfloetz** – sand layer; interlayer under fourth *serie* in Fuchel’s stratigraphy of Thuringia.

**Schichten** – beds, strata.

**Spezielle Gang-Formazionen** – special vein formations; veins in universal formations.

**Stand** – position (for example, some mountains in relation to others).

**Uebergangsgebirge** – Transition (mountain ranges) rocks; the second unit of Neptunist general stratigraphy.

**Urgebirge** – primitive (mountain ranges) rocks; the first unit of Neptunist general stratigraphy.

**Uranfaengliche Gebirge** – synonym of *Urgebirge*.

**Untergeordnete Bergarten** – subordinate (mountain ranges) rocks (= formations).

**Unterlager** – interlayer between two *serie montana* (= formations).

**Wechsel** – change.

## Резиме

### Оригинално значење појма и термина „формација“ у геологији

Појам (геолошка) формација постепено је уобличаван под разним претежно немачким називима: од „ein Gebirge“ из вишевековне праксе саксонских рудара (Agricola, 1521, стр. 167), преко „Schichten“ и „Bergart“ (LEHMAN, 1756, стр. 162 и 168) до „Gebirgsart“ (WERNER, стр. 5). Термин „формација“ (Formazion) увео је WERNER 1791. (стр. 5–6).

WERNER је око 1800. године појам и термин „формација“ дефинисао као „одређену заједницу сличних или различитих стенских маса које се карактеришу као једна независна целина по својим спољашњим и унутрашњим односима, т.ј. као јединица у низу стенских творевина, ... препознаје се по особинама, које су сваки период и начин формирања оставили као траг у њој“ (по OSPOVAT-у, 1999, стр. 15). При томе, аутор је разликовао формације по њиховом материјалном саставу, распрострањењу и суперпозицији.

Веома значајно је што је Werner појам „формација“ увео у свој систем „геогностичких структура“ у низу: минерал – стена (слој) – формација – земљина кора (по AUBUISSON DE VOISINS-у, 1828, стр. 267–269). Због тога је термин „формација“ добио вишезначан смисао. Подразумевао је у исто време геолошко тело одређеног састава, постанка и суперпозиционог положаја (односно времена када је настало).

Werner-ови ђаци и следбеници већином нису разумели зашто је он формацији одредио више-

значност. Мислили су да је то озбиљна грешка, критиковали су то и заузимали различите ставове у погледу коришћења тог термина.

Занимљиво је да је LYEL (1855, стр. 3, 1874), доста усамљено заступао оригинално Werner-ово схватање формације, чак и онда када су га готово сви напустили и заборавили.

Током XIX stoleћа преовладао је став да формација може да има само једно, и то – хроностратиграфско значење. Тако је овај термин сведен на синоним за „систем“. На тај начин слободно и широко је био у употреби до II Међународног геолошког конгреса у Болоњи 1881. године, када је то изричито забрањено. Упркос забрани, међутим, погрешна употреба термина формација настављена је у неким школама и у XX веку.

Између 1930. и 1980. године, посебно после 1945., појам и термин „формација“ и њихово практично коришћење били су предмет повећаних расправа између различитих геолошких школа. (Највише их је било у СССР-у.) У дефинисању и издвајању формација коришћени су литостратиграфски, парагенетски, разни генетски и комплексни принципи. То је довело до успостављања различите праксе формационе анализе. На основу целокупног тог искуства ДРАГУНОВ (1965) је дефинисао формацију као „елементарно природно тело које заузима ниво између стене и геосфере у хијерархији организације материје“. Тако је овај аутор дошао до истог фундаменталног става који открио и промовисао Werner.

Формација, као назив за елементарно природно тело, као и термини за сва друга таква тела, мора и може да буде само вишезначна јер је то иманента особина сих тих назива. Због тога се формација другојачије дефинише и издваја, и примењује на специфичан начин у разним геолошким дисциплинама; баш исто као што је то случај са минералом, стеном геосфером и планетом. Формација није термин слободне употребе, да би се користио без икаквог правила, већ је то термин „вишезначан“. То значи, када се наведе, онда тачно мора да се зна како и зашто је тако употребљен (н.пр. у стратиграфији, геолошком картирању, металогенији, хидрогеологији итд.)

После свих авантура, у другој половини XX века враћен је „формацији“ њен изворни вернеријански смисао: „вишезначност“ термина и појам „елементарне јединице у геолошким нивоима организације материје: минерал – стена – формација – геосфера – планета. У овом низу свака претходна јединица је елементарна према следећој, која припада вишем нивоу поменуте организације. Укратко – „формација“ је данас основни објекат проучавања „Формационе геологије“, односно скупа геолошких дисциплина у којима се она испитује и користи.