

OBJECTIVES OF THE FIRST NATIONAL CONFERENCE ON CLAYS AND CLAY TECHNOLOGY AND DEFINITIONS OF TERMS USED IN THE INDUSTRY

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Clay mineralogy is a very broad subject that includes work in many different fields: in chemistry, physics, mineralogy, and geology; in the applied fields of ceramics, engineering, and agriculture. Workers in clay mineralogy have come into it from many different disciplines, and they have many special interests. However, workers in clay mineralogy and technology, regardless of their special interests, have much in common, because basically their problems all revolve around the structure, properties, origin, and occurrence of clay minerals. An extension of the knowledge of any of these attributes of the clay minerals will be of value to all workers in the field.

Students of clay mineralogy and clay technology in the United States have realized for some time that much was to be gained by a meeting of all workers in this field, regardless of their special interest or the particular discipline through which they approached their problems. The meeting together of ceramists, engineers, agricultural chemists, mineralogists, and physicists, to discuss aspects of clay mineralogy on which each has worked and thought, cannot but be stimulating and lead to new ideas and concepts.

In accordance with the thought that progress in clay mineralogy and clay technology would be enhanced by the cooperative effort of all workers in the field regardless of their special interest or discipline, a National Clay Minerals Committee was established in St. Louis at the time of the 1951 national meeting of the American Institute of Mining and Metallurgical Engineers to explore the desirability and feasibility of starting some kind of an association to include all workers in clay mineralogy. The committee, of which I have the pleasure of serving as chairman, unanimously approved a plan to affiliate with the National Research Council, at an open meeting on July 22, 1952.

Objectives of the Conference. For the arranging of the present conference, clay mineralogists and technologists everywhere are indebted to the University of California group, and to Professor Joseph A. Pask in particular. It has been a tremendous amount of work, and a magnificent job of organizing and planning has been done.

The objective of this conference is to bring together workers in clay mineralogy and clay technology so that they may express their ideas and discuss their problems, and in this way learn a little more about the occurrence, structure, and properties of the clay minerals, and the way in which the properties influence the large rock-properties of clay materials, which in turn determine the manner of use or the way in which they can best be controlled in engineering. The conference provides also an opportunity to discuss matters on which there are differences of opinion, so that some agreement may be reached on controversial points.

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Definitions of Terms. In the field of clay mineralogy and clay technology, there are a few terms which have more than one meaning, or are used differently by workers approaching the subject from different fields. Thus, the term clay itself is used to designate a rock with certain physical attributes and a certain general composition. It is also used as particle-size term to designate the fraction of a rock composed of particles finer than a certain size grade. Unfortunately the upper limit of the size grade designated as clay is not the same in all fields. Geologists, for example, place the limit at 4 microns, whereas many others place it at 2 microns. In the case of the size-grade designation, there seems to be a growing tendency to use "clay grade" or "clay size grade" and to reserve clay as a rock term. This is a gratifying advance.

Clay, as a rock term, is difficult to define precisely. It is a natural material, very fine grained, and essentially composed of silicate minerals—the clay minerals; very fine-grained natural materials of other compositions, such as bauxites and diatomaceous earths, probably should be excluded. Further, clays are earthy and with few exceptions (notably the flint clays) are plastic when mixed with water. A brief examination will permit almost anyone familiar with clays to decide whether a given material should be so classified. There are, however, some borderline materials containing appreciable amounts of minerals other than the clay minerals on which all workers would not agree as to whether they should be termed clays. This is bound to be true, since nature did not make all materials to fit into man-made compartments.

Soil is another term used differently by different groups interested in clay mineralogy. Soil to the geologist is the weathered regolith at the earth's surface that supports vegetation. To the agronomist, soil is the loose regolith at the earth's surface, but it need not be weathered nor support any vegetation—it may be gravel, for example—which the geologist would never call soil. To the civil engineer, soil is any loose material at the earth's crust regardless of particle-size distribution, composition, or organic material. The engineer (Terzaghi and Peck, 1948) divides the material of the earth's crust into two categories: hard consolidated material or rock, and loose material called soil. The geologist is frequently surprised to hear the engineer speak of a deeply buried gravel zone as a soil. These definitions of soil are deeply entrenched, and it is my opinion that redefinitions would not be accepted or used. Workers in the field must know the variation in definition as used by different groups of workers.

Shale is another term which has some variation in definition. To the geologist the term indicates a laminated material with the lamination parallel to the bedding and one which has not been metamorphosed to the extent of developing new minerals. To others, shale is merely a hard, indurated clay.

I have found the expression "clay material" very useful in writings destined for several groups which may have somewhat different definitions of clay, soil, etc. It implies any argillaceous material composed largely of the clay minerals, whether or not it is weathered, at the earth's surface, plastic, or laminated.

With regard to definitions of the clay minerals, it seems to me that workers are in remarkably good agreement. Halloysite minerals are an exception and the situation is well known. In my opinion the best solution to the halloysite nomenclature problem was that suggested by the group meeting in Amsterdam in 1950 at the time of the International Soils Congress (1951). This group recommended that halloysite be used as a general group name and that when the state of hydration of a sample was known a suitable descriptive prefix or suffix be used, such as halloysite ($2\text{H}_2\text{O}$). It is too soon to tell whether this suggestion will be followed by clay investigators generally.

There is still some variation in the usage of a term for the mica clay minerals, excluding the chlorite and vermiculite types, although the general term illite for all such clay minerals is very widely used. The problem of the nomenclature of the illite minerals is exceedingly difficult because of their range in composition and structural attributes, and because there appear to be gradations between forms which at their extremes have very different properties. An example is the probable gradation from expanding lattice to non-expanding lattice minerals. A further difficulty is that the illites frequently occur in mixed-layer structures. It is, for example, sometimes difficult to tell whether a sample composed largely of illite shows a slight lattice expansion or contains a few mixed layers of montmorillonite. In my opinion a satisfactory nomenclature and classification for these minerals cannot now be derived. Additional information on the range of composition and structure, and perhaps better criteria for identifying the various possible forms of these minerals are needed before a satisfactory classification can be worked out. In the meantime, it is essential for all of us to describe our samples as precisely as possible from the standpoint of structure and composition. We particularly need additional data on samples of pure illite. Unfortunately, samples of illite uncontaminated by other material are hard to find.

Clay and soils have been studied in some fashion ever since people became curious about natural things. Investigations into the nature of clay materials—the building blocks which compose them—date back about to the beginning of scientific research. The clay materials proved particularly difficult to study because they are extremely fine grained and because many of them are very complex mixtures. About 30 years ago new research tools, particularly X-ray diffraction, became available, which permitted for the first time precise determination of the identity and character of the components of clay materials. Since the early nineteen twenties, additional analytical tools, such as differential thermal analysis and electron microscopy, have been developed and adapted to clay analysis.

With the development of the new or improved research tools, there came a great expansion of interest in clay research. Many new workers began to devote them-

selves wholly to clay studies. In many fields in which clay materials are important, serious basic studies of composition and properties previously neglected, were undertaken. There has been in the last 30 years, but particularly in the last 15 years, a great flowering of clay research. I think everyone will agree that a vast amount of sound fundamental knowledge about clay materials has been gained in this interval. The gain has come from the work of people in many fields—chemists, mineralogists, physicists, engineers, and agronomists. Indeed, clay mineralogy is fortunate in attracting workers from many fields. Its ramification into so many fields is perhaps its greatest attraction for many research workers.

The flowering of clay studies has led to the general acceptance in all disciplines of the clay-mineral concept of the nature of clays. Engineers, soil scientists, ceramists, and others are beginning to think of their problems in terms of clay mineralogy, although the concept is by no means universally known. Only a few months ago a paper appeared in a leading geological journal in the United States in which the author blandly assumed that all argillaceous sediments were composed of kaolinite and proceeded to develop elaborate theories on that basis.

At this point I would like to inject a word of caution. Some of us were perhaps led to carry the notion of clay mineralogy to the extent of considering all clay materials to be composed solely of crystalline substances. Recent studies have shown that there are some clay materials—probably not very many, but some—which do have some material which seems to be amorphous. Such material may be very hard to identify and the question of whether a component has a very low degree of organization or is completely amorphous sometimes cannot be decided.

The great strides that have been made in clay mineralogy do not mean that all problems have been solved. Indeed, the large areas of this field where knowledge is particularly needed, and for which much information is likely to come in the immediate future, can only now be seen clearly.

Structural studies are, of course, the underlying fundamental work that must precede almost any other investigations. Further information on the structure of montmorillonite and illite is needed: data on the exact population of the octahedral and tetrahedral positions; the site of the charge; the limits of composition for the expanding lattice; an explanation of the great difference in the catalytic properties of various montmorillonites; the nature of possible reactions between adsorbed organic molecules and the montmorillonite structure; and a solution to the apparent discrepancy between X-ray and electron microscopic data for halloysite.

Information on the system clay-minerals-water is essential to an understanding of such properties as plasticity, bonding strength, and sensitivity, which frequently determine the utility of a clay material. There is general agreement, I believe, that the initially adsorbed water is not liquid water; but further information on the exact nature of this water—the influence of adsorbed cations and anions—its variation with relative humidity and distance from the clay mineral surface—is needed.

Textural studies of clay materials in their natural state are the least far advanced. What holds relatively loose clay materials together—what is the nature of the bonding force—what is the influence of water, and of various ions—are not known. Engineers are particularly interested in this problem. It is not enough to tell them that a soil is composed of illite and quartz—they need to know how the clay mineral particles fit together and what holds them together. Unfortunately, no one has yet devised adequate techniques for studying the texture of clay materials in their natural state.

Another frontier is the change that takes place when clay minerals are heated. What actually happens when the hydroxyls are driven off—what determines the temperature at which they are lost—what is the nature of the structural shift when a new phase develops? Such studies have great practical value in the field of ce-

ramics. They also have great general scientific value and some research going forward in this field may well alter our thinking about the interpretation of phase diagrams. Fortunately the development of high-temperature X-ray techniques permitting the determination of the phase at an elevated temperature while it is in the furnace has greatly enhanced researches in this field.

Other frontiers could be mentioned: for example, the essential conditions for the genesis of the various clay minerals; but the foregoing will suffice to show that actually we do not yet know very much about clay materials.

SELECTED REFERENCES

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