Definition of a mineral

Introduction

In response to suggestions from the mineralogical community that a new definition of a mineral, compatible with recent technological advances, should be promulgated, the IMA Commission on New Minerals and Mineral Names (CNMMN) has taken the initiative in producing the definition embodied in this paper. The paper is the end-product of active discussion of the subject within the CNMMN over a period of several years, and represents a general consensus of the CNMMN membership.

Although the main purpose of this definition is to provide internal guidelines for the work of the CNMMN, it is hoped that it will be also be generally accepted by mineralogists and other earth scientists when faced with the problem of deciding whether a particular substance should be classed as a mineral. The definition is not intended to be retroactive, i.e., substances that fall outside the scope of the definition but which have been accepted as minerals in the past are not to be automatically discredited by this publication.

In general terms, a rnineral is an element or chemical compound that is normally crystalline and which has been formed as a result of geological processes. This statement suffices to include the vast majority of substances that are generally accepted as minerals, but there are some substances that do not conform entirely to these requirements and it is therefore necessary to consider where the dividing line between mineral and non-mineral should be drawn, and what exceptions to the general statement should be permitted. The remainder of this document is devoted to an examination of these aspects

Crystallinity

The term "crystalline", as generally used in mineralogy, means atomic ordering on a scale that can produce an "indexable" (i.e. with Miller indices) diffraction pattern when the substance is traversed by a wave with a suitable wavelength (X-ray, electrons, neutrons, etc.). However, some naturally-occurring substances are non-crystalline. Such substances can be divided into two categories: amorphous — substances that have never been crystalline and do not diffract X-rays or electrons; and metamict — those that were crystalline at one time, but whose crystallinity has been destroyed by ionizing radiation. Some mineralogists are reluctant to accept amorphous substances as minerals because of the difficulty in determining whether the substance is a true chemical compound or a mixture, and the impossibility of characterizing it completely; some prefer to call such substances "mineraloids". However, some amorphous substances (e.g. georgeite, calciouranoite) have been accepted as minerals by the CNMMN.

With modern techniques it is possible to study amorphous phases more effectively than was possible in the past. Spectroscopic methods associated with a complete chemical analysis can often identify an amorphous phase unequivocally. In fact, appropriate spectroscopies (e.g. IR, NMR, Raman, EXAFS, Mössbauer) can reveal the three-dimensional short-range structural environment of each element (chemical bonds). Of course, without the possibility of obtaining a complete crystal structure analysis, which can give coordinates and nature of the atoms, the necessity of a complete chemical analysis is more stringent with amorphous material than with a crystalline phase.

The basis for accepting a naturally-occurring amorphous phase as a mineral could be;

— a series of complete quantitative chemical analyses that are sufficient to reveal the chemical composition of all the grains in the specimen;
— physicochemical (normally spectroscopic) data that prove the uniqueness of the phase;
— evidence that the material cannot produce an "indexable" diffraction pattern, both in the natural state, and after treatment with some physico-chemical solid-state process (e.g. heating).

Metamict substances, if formed by geological processes, are accepted as minerals if it can be established with reasonable certainty that the original substance (before metamictization) was a crystalline mineral of the same bulk composition. Evidence for this includes the restoration of crystallinity by appropriate heat treatment and the compatibility of the diffraction pattern of the heat-treated product with the external morphology (if any) of the original crystal (e.g. fergusonite-Y)).

A special case of non-crystalline naturally-occurring substances are those that are liquid under ambient conditions. Water, in its liquid form, is not considered to be a mineral, but its solid form, ice, is. Mercury, however, is recognized as a mineral even though it does not occur in a crystalline state on Earth. Petroleum and its non-crystalline bituminous manifestations, are not regarded as minerals.

Stability under ambient conditions

Many minerals were formed under conditions of high temperature and/or pressure and are metastable under ambient conditions; others may tend to hydrate or dehydrate when removed from their place of origin. Such minerals may require special procedures to prevent their decomposition before the investigation is complete. The use of special procedures in the investigation does not preclude the acceptance of a metastable or unstable substance as a mineral if it can be adequately characterized and if it meets the other criteria for a mineral.

Extra-terrestrial substances

Extra-terrestrial substances (meteorites, moon rocks, etc.) were apparently produced by processes similar to those on Earth, and therefore such processes are now called geological, even though the term "geology" originally meant the study of rocks on this planet. Consequently, naturally-occurring components of extra-terrestrial rocks and cosmic dusts are regarded as minerals (e.g. the lunar mineral tranquillityite).

Anthropogenic substances

Anthropogenic substances are those produced by Man, and are not regarded as minerals. If such substances are identical to minerals, they can be referred to as "'synthetic equivalents" of the minerals in question.

Geologically-modified anthropogenic substances

Chemical compounds formed by the action of geological processes on anthropogenic substances have, on occasion, been accepted as minerals (e.g. the Laurium 'minerals' formed by the reaction of seawater with ancient metallurgical slags). However, in the modern era, when many exotic materials are produced, the possibility arises that such substances can be placed in a geological environment to produce reaction products that might otherwise qualify as new minerals. The CNMMN has therefore ruled that, in future, chemical compounds formed by the action of geological processes on anthropogenic substances cannot be considered as minerals.

Some chemical compounds formed by the action of geological processes on rocks or minerals that have been exposed to such processes by activities of Man (e.g. mine openings, ore dumps, road cuts, etc.) have been accepted as minerals in the past and, if the exposure was inadvertent, i.e., not done with the express purpose of creating new minerals, then such products can be accepted as minerals. Chemical compounds caused by mine fires are considered to be a special case, as it is not always clear whether there has been human involvement in initiating the fire, and such substances are therefore not accepted as minerals.

Biogenic substances

Biogenic substances are chemical compounds produced entirely by biological processes without a geological component (e.g. urinary calculi, oxalate crystals in plant tissues, shells of marine molluscs, etc.) and are not regarded as minerals. However, if geological processes were involved in the genesis of the compound, then the product can be accepted as a mineral. Examples of acceptable minerals of this kind are substances crystallized from organic matter in black shale or from bat guano in caves, and the constituents of limestones or phosphorites derived from marine organisms.

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