Chapter 2

Hydrostratigraphic units

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INTRODUCTION

Geologists have long agreed upon the need for consistent, explicit methods of dividing local rock sequences into separate units. The stratigraphic procedures and principles that have evolved define a stratigraphic unit as a naturally occurring body of rock distinguished from adjoining rock on the basis of some stated property or properties (North American Commission on Stratigraphic Nomenclature, 1983, p. 847). Codes of stratigraphic nomenclature prepared by the North American Commission on Stratigraphic Nomenclature (NACSN, 1983) and the International Subcommission on Stratigraphic Classification (ISSC, 1976) are now widely used for stratigraphic terminology and classification. A stratigraphic code or guide is a formulation of current views on stratigraphic principles and procedures and is designed to promote standardized classification and formal nomenclature of rock materials.

In stratigraphic work, two basic categories of units are now recognized: (1) material units, based on actual bodies of rock; (2) nonmaterial units, based on the abstract concept of time (Owen, 1987, p. 363). A combination of these two categories, a chronostratigraphic unit, is also commonly recognized. These are equivalent to the older “holy trinity” of rock units, time units, and time-rock units.

A standard method of classification facilitates the systematic arrangement and partitioning of rock or unconsolidated materials of the Earth's crust into units based on their inherent properties and attributes, and in turn, the geologic mapping and regional correlation of such units. This standardization promotes the systematic and rigorous study of the composition, geometry, sequence, history, and genesis of rocks and unconsolidated materials. A number of different standardized bases exist for dividing rock units now in use in North America. Commonly used properties include composition, texture, included fossils, magnetic signature, radioactivity, seismic velocity, and age (NACSN, 1983, p. 847).

Units based on one property commonly do not coincide with those based on another, and therefore, geologists have found that distinctive terms and criteria are needed to identify and describe the property used in defining each type of material unit (NACSN, 1983, p. 847). Stratigraphic units used by hydrogeologists, herein termed hydrostratigraphic units, are an example of a type of unit lacking distinctive criteria that permits formal definition and classification. The adjective stratigraphic is used here in the broad sense to refer to stratigraphic procedures and principles which are now applied to all classes of earth materials.

Hydrostratigraphic units were originally defined as bodies of rock with considerable lateral extent that compose a geologic framework for a reasonably distinct hydrologic system (Maxey, 1964, p. 124). A hydrostratigraphic unit was intended by Maxey to become a specialized category within the framework of a code of stratigraphic nomenclature that would allow geologists to express clearly and precisely the similarities, parallels, and contrasts between ground-water entities and other units recognized by the code. A hydrostratigraphic unit was also intended to be the practical mappable unit for ground-water studies, equivalent in rank to formation in rock-stratigraphic classification. It was intended to serve as a fundamental unit for describing hydrogeologic systems in the field based on the properties of the rock that affect ground-water conditions and would be of tested mappability. However, Maxey (1964) included the dynamics of the hydrological regime in his concept and definition of the hydrostratigraphic unit. This condition, because it is not a material property of any rock unit, is a factor that does not allow formal adoption of this concept of hydrostratigraphic units by the North American Commission on Stratigraphic Nomenclature.

Rules of the U.S. Geological Survey (USGS, 1890, 1903) and the codes of stratigraphic nomenclature by the predecessors of NACSN, the Committee on Stratigraphic Nomenclature (CSN, 1933) and the American Commission on Stratigraphic Nomenclature (ACSN, 1961, 1970), as well as the International Stratigraphic Guide (ISSC, 1976), designate the formation (Lyell, 1858) as the basic building block of all geologic mapping. Originally, a formation could mean any assemblage of rocks that had some character in common, whether of age, origin, or composition. Only later (ACSN, 1961) was emphasis placed on the lithic or solid rock characteristics. Hydrogeologists have related their hydrogeologic units to a classical geologic framework of lithologic character, stratigraphic association, and sometimes, to fossils contained in the rocks. This practice has created problems and...
difficulties for field hydrogeologists who have mapped and defined hydrogeologic units based not only on the character of the solid rock material (lithic), but also on that of the interstices.

Hydrogeologists have recognized the need to develop an appropriate set of principles and procedures for classifying and naming hydrostratigraphic units that would allow consistent mapping of these units. Problems with usage of stratigraphic terminology are discussed by Owen (1987). Jorgensen and Rosenzweig (1987) review the confusion resulting from naming aquifers, which probably occurs because of inexact or inaccurate definitions of an "aquifer." Much of the confusion in classifying and naming hydrostratigraphic units occurs because the nature and boundaries of the unit have not been defined before mapping the unit. An additional disagreement among hydrogeologists seems to be whether to map and name the flow system and the rock body separately, or to find a means to combine the two concepts into one system of mapping and nomenclature.

Current stratigraphic and hydrogeologic concepts and principles must be used to solve this dilemma, and the classification procedures and principles adopted must be flexible in order to provide for both change and additions that may be needed to improve their relevance to new scientific problems. To be effective, the procedures must be widely used and accepted. This chapter discusses the historical background and presently used concepts in the mapping, classification, and nomenclature of water-bearing and non-water-bearing deposits in North America.

EVOLUTION OF A STRATIGRAPHIC CODE

The scientific classification and nomenclature of hydrogeologic units closely parallels, but has lagged behind, the conceptual evolution of stratigraphic procedures and practices applied to other types of rock units. Scientific classification of rocks deals with defining the nature and boundaries of a unit. Nomenclature deals with establishing the rank and hierarchy of that unit and assigning a unique name or words to give it a distinctive designation. Arguments over rank and nomenclature are futile whenever the criteria used to determine the nature and boundaries of a unit are not clear, which is the present case for hydrostratigraphic units.

This chapter focuses on the relation of stratigraphy and hydrogeology. This section of the chapter deals with evolving stratigraphic concepts, particularly of the term formation, which is entrenched in hydrogeologic literature in relation to the term aquifer. In practice, an aquifer is an abstraction that is by no means equivalent to a single geologic, lithologic, or stratigraphic unit (Marsily, 1986, p. 115). Many hydrogeologists have extensive geologic backgrounds and they use stratigraphy to name aquifers (Jorgensen and Rosenzweig, 1987, p. 210). Conversely, many other geohydrologists, without this extensive geologic background, have used hydrologic terminology and concepts to define aquifers. Therein lies a major source of confusion in the classification and nomenclature of hydrogeologic units.

The attempts of geologists to separate, correlate, and map rocks have focused on: (1) cartographic representation, (2) intelligible description, (3) historical interpretation, and (4) regional correlation. Geologists have always made "must be mappable" a significant and critical criterion in rock classification and nomenclature. Historically, geologists have used the formation as the fundamental mapping unit of all rocks from the time of Lyell (1858) to the publication of the "North American Stratigraphic Code" (NACSN, 1983). Lyell's basic building block of geology was defined as "any assemblage of rocks which have some character in common, whether of origin, age or composition." It was mappable. The common character could be lithology, genesis, or age.

One of the earliest attempts at standardization of representation of mapping units is given in the Tenth Annual Report of the U.S. Geological Survey (USGS, 1890, p. 63–79), which for cartographic purposes divided all rocks into four great classes: (a) fossiliferous clastic rocks, (b) surficial deposits, (c) ancient crystalline rocks, and (d) volcanic rocks. For clastic rocks the two classes or divisions were the structural and time divisions. The time divisions were the 11 periods of geologic time. The structural divisions were the units of cartography used for mapping and were designated formations. Formation essentially meant Lyell's definition, but, "In every case the definition should be that which best meets the practical requirements of the geologist in the field and the prospective user of the map: that is to say, each formation should possess such characteristics that it may be recognized on the ground alike by the geologist and by the layman" (USGS, 1890, p. 64). Hydrogeologic units were not recognized in this report.

The Twenty-Fourth Annual Report of the U.S. Geological Survey (1903) extensively revised the earlier rules and recognized for cartographic purposes three great classes of rock: (a) sedimentary, (b) igneous, and (c) metamorphic. All cartographic (mappable) units were called "formations." For sedimentary rocks, "The formation should . . . be traced and identified by means of its lithologic character, its stratigraphic association, and its contained fossils" (USGS, 1903, p. 23). Igneous formations were discriminated on the basis of mode of occurrence, chemical composition, and mineral and textural characteristics (USGS, 1903, p. 24). Metamorphic formations were discriminated on the basis of their petrographic characters (USGS, 1903, p. 25).

This system prevailed until the first code of stratigraphic nomenclature was published (Committee on Stratigraphic Nomenclature, 1933). The 1933 code and the 1903 U.S. Geological Survey "rules" are very similar, and most state geological surveys adopted the 1933 code. In the 1933 code, a sedimentary rock formation was defined as a genetic unit formed under uniform depositional conditions, was of limited horizontal extent, and of supposedly uniform lithology. Hydrogeologists of the day related groundwater to this classical framework of lithologic character, stratigraphic association, and contained fossils, where present in
sedimentary rocks, or to the igneous and metamorphic formation characteristics. Neither aquifers nor any other hydrogeologic units are mentioned in the 1933 code.

A new Code of Stratigraphic Nomenclature was developed between 1933 and 1961 (ACSN, 1961). Categories of stratigraphic units were named rock-stratigraphic, soil-stratigraphic, biostratigraphic, and time-stratigraphic, and the nonmaterial units were termed geochronologic and geologic-climate units. The formation was still the basic rock-stratigraphic (lithostratigraphic) formal mapping unit for all rock types. The major change from the 1933 code was that time, genesis, and fossil content were no longer basic criteria used in defining a formation. Formal units, essentially those requiring stability of nomenclature, as well as informal units, were used. Aquifers were mentioned as informal units in the 1961 code, and were lumped with other economic and utilitarian units such as coal beds, quarry layers, oil-bearing reefs, and oil sands.

The 1970 American Code of Stratigraphic Nomenclature (ACSN, 1970) and the 1976 International Stratigraphic Guide (ISSC, 1976) mention aquifers, which could, if stratigraphically significant, be recognized as beds, members, and formations. The term formation is applied in all three of these codes (1961, 1970, and 1976) to all rock types, based strictly on observable physical features. A formation had to possess some degree of internal lithologic homogeneity or distinctive lithologic features. Accordingly, formations were lithic units and remained the basic practical unit of geologic work. The terms rock-stratigraphic and lithostratigraphic were considered to be synonymous.

The 1983 Code of the North American Commission on Stratigraphic Nomenclature contains six major categories of material units and several units based on age. This code has material categories of units based not only on lithic (used as synonymous with "lithologic") characteristics, but also on content, inherent attributes, or physical limits. Rock units, as used in earlier codes and codes, is a term that could be used as a synonym for material categories of units. The material categories include lithostratigraphic, lithodemic, magnetopolarity, biostratigraphic, pedostratigraphic, and allostratigraphic units. The basic building blocks for most geologic work are rock bodies defined on the basis of composition and related lithic characteristics, or on their physical, chemical, or biologic content or properties. Emphasis is placed on the relative objectivity and reproducibility of data used in defining units within each category (NACSN, 1983, p. 848).

In the 1983 code, the term "formation" is restricted to lithostratigraphic units that are generally stratified, tabular rock bodies conforming to the Law of Superposition. It is not used with lithodemic units, which are mostly igneous or metamorphic rocks, or with allostratigraphic units, which are recognized by bounding disconformities. Neither does it apply to the other material categories. For nonstratiform rocks (of plutonic or tectonic origin, for example), the parallel term lithodeme is used. The term rock-stratigraphic is no longer used formally in the 1983 Code nor in the International Stratigraphic Guide, since stratigraphic in a restricted sense in limited to stratiform rocks.

The interstices (voids) in rocks, which create the porosity and permeability mapped by hydrogeologists, are not mentioned in the 1983 code as a rock property. Aquifers are mentioned as informal economic units or as possible formal lithostratigraphic units, but not as lithodemic or allostratigraphic units even though the latter two types of units may be water bearing. Definitions of hydrogeologic units, such as aquifer, that rely on the formation as a basic part of their definition are thus outdated if the 1983 code is adhered to for hydrogeologic work.

HISTORY OF HYDROGEOLOGIC MAPPING

Perhaps the best publication dealing with the historical treatment of hydrostratigraphic units (i.e., ground-water units) is entitled Hydrological Maps (UNESCO, 1977, p. 135–190), wherein four stages of development of ground-water mapping are discussed. Paraphrasing freely, these are: (1) relating ground water to the classical geologic (lithostratigraphic) framework without detailed regard for hydraulic continuity, (2) relating ground-water occurrence to the hydraulic properties within the classical geologic framework, (3) showing ground water as a resource, and (4) showing the relationship of ground water to the water-bearing characteristics of the rocks and to the dynamics of the hydrological regime. The kind of ground-water mapping done was strongly influenced by the existing rules or stratigraphic code of the day.

Before 1923, geologists doing hydrogeological mapping, such as Chamberlain (1897), Darton (1896), Ellis (1916), King (1898), Leverett (1896, 1899), Mendenhall (1905), Mendenhall and others (1916), Norton and others (1912), and Slichter (1899), simply spoke of a formation as a water-bearing or non-water-bearing unit. This early stage of ground-water mapping had the advantage of showing the extent to which the geology of an area could provide clues to the occurrence, distribution, and movement of ground water without regard to hydraulic continuity.

Meinzer (1923b, p. 30) states, "An aquifer is a formation, group of formations, or part of a formation that is water-bearing. This definition essentially classifies and maps rocks and formations according to their water-bearing properties and relates ground-water occurrence to the hydraulic properties within the classical geologic framework. Meinzer (1923a, 1923b) clearly recognized in his definition of an aquifer that formations were not everywhere exactly equivalent to either water-bearing or non-water-bearing units. He would have had no need to invoke the concept of an aquifer if they were, and could have easily referred to them simply as water-bearing or non-water-bearing formations as previous geologists did. His definition of an aquifer was utilitarian and practical, and he used the terms ground-water reservoir, water-bearing bed, water-bearing stratum, and water-bearing deposit as synonyms of aquifer. Meinzer (1923a) also classified and mapped water-bearing units by geologic age. He coined no word or term for non-water-bearing rocks except confining beds, which, because of their position and their impermeability or low permeability relative to that of the aquifer, give the water in the
aquifer either artesian or subnormal head (Meinzer, 1923b, p. 40). Other workers used terms such as aquitard, aquichute, and aquifuge to classify rocks that were not aquifers but were equivalent, in part, to Meinzer’s “confining bed” concept.

Maps that show ground water as a resource began appearing in the 1950s, but initially these maps showed no direct relation with either the rock column or the flow system. About the same time, maps that related the water-bearing characteristics of the rocks to the dynamics of the flow system appeared. An early example of this type of map is that of the Baltimore, Maryland, area (Bennett and Myer, 1952), which built on the earlier work of Darton (1896, p. 142–148). The important differences between this type of map and earlier maps is that aquifers and confining beds are mapped as distinctive, independent units whereas earlier hydrogeologic maps related the water-bearing characteristics to specific geologic units. This new concept in mapping turned out to have many practical and utilitarian purposes, particularly in modeling efforts.

Maxey (1964) first proposed the term hydrostratigraphic unit in order to map ground-water occurrence and relate it to the water-bearing characteristics of the rocks and to the dynamics of the hydrologic regime. The terms aquifer and confining bed were redefined (Lohman, 1972) to show their relationship to the rock column and to the dynamics of the hydrological system, as did Poland and others (1972), who also defined the term aquifer system. Many aquifers and confining beds have been mapped. Most frequently these are stratiform water-bearing deposits (aquifers) and, if present, their overlying and/or underlying confining beds.

Another stage of development of ground-water mapping is to relate water-bearing and non-water-bearing characteristics to the rock column without trying to make these physical rock attributes (porosity and permeability) conform to other mappable material (rock) units, or to the dynamics of the hydrologic regime (Seaber, 1982, 1986). Such a technique forces a redefinition of Maxey’s hydrostratigraphic unit and defines, as well as maps, a hydrogeologic unit as a body of rock distinguished and characterized by its porosity and permeability. This redefinition of a hydrostratigraphic unit ties such a unit to the rock column, but not necessarily to the dynamics of the flow system, which can be ephemeral in terms of geologic time and is subject to changes by the work of man. This type of mapping allows hydrostratigraphic units to be considered for formal inclusion in the North American Stratigraphic Code as a unique type of material unit, which thus could be mapped independently of, but related to, other rock units.

Many types of available geologic maps can be utilized to aid in hydrogeologic mapping. King (1969, Fig. 5, p. 12–13) presents three ways of depicting the geology of an area. The area shown on his maps represents an area in eastern Tennessee and western North Carolina, including portions of the Valley and Ridge and Appalachian Plateau physiographic provinces. The maps show: (a) time-stratigraphic units (geologic systems), (b) rock-stratigraphic systems (structural stages), and (c) structure showing folds and faults. A hydrogeologic map would most clearly resemble the rock-stratigraphic map, although it would not everywhere be a map of permeability and porosity (i.e., hydraulic properties). However, all three types of geologic mapping are important aid to some aspect of hydrogeologic mapping.

HISTORICAL DEVELOPMENT OF HYDROGEOLOGICAL CLASSIFICATION AND NOMENCLATURE

Conventional geologic mapping has tended to concentrate only on the solid rock material. The character of the interstices in the rock might be noted (e.g., whether they are primary or secondary), but interstices are never used as a primary feature for mapping. Geologists, however, recognize that intrinsic permeability and porosity are fundamental attributes of all rocks, whether consolidated or unconsolidated, stratiform or nonstratiform. Hydrogeologists use combinations of the character of the solid rock material, the type and variations of the interstices, and the flow patterns of the water in the rock as mapping criteria. Field work has demonstrated that hydrostratigraphic units can be defined and mapped on the basis of physical properties and attributes, and also that flow systems in rocks can be mapped using water level and other data. But hydrogeologists do this mapping without uniform practices and procedures; they are lacking a “Hydrogeologic Code” similar to the present 1983 North American Stratigraphic Code.

Without formally established and universally accepted hydrostratigraphic procedures and principles, it is difficult for hydrogeologists to bring scientifically ordered terminology to their field studies, including mapping of hydrogeologic units. This problem is compounded because hydrogeologists themselves have not agreed upon a scheme for hydrostratigraphic classification and nomenclature based on mappable hydraulic properties or other attributes important to hydrogeology and ground-water investigations.

Meinzer (1923a) coined the words aquifer and confining bed. Tolman (1937, p. 36–37) coined the word aquiclude to categorize a “formation,” that absorbs and transmits water slowly, and gave credit to Davis (1930, p. 488) for the word aquifuge, which is used to describe impervious rocks. Davis originally used “aquifuge” to apply to rocks with the characteristics of both “aquiclude” and “aquifuge” as used by Tolman, but later agreed to Tolman’s more restricted usage of the word.

John Ferris coined the word “aquitard” (as better Latin) to replace the term aquiclade in courses given to U.S. Geological Survey ground-water personnel in 1958. Aquiclude means confinement of, rather than the exclusion of, water. Aquiclade, in this sense, may be thought of as a synonym for the hydraulic term confining bed. Todd (1980, p. 26) discusses the Latin origin of some hydrostratigraphic terms: “The word aquifer can be traced to its Latin origin. Aqui- is a combining form of aqua (“water”) and -fer comes from ferre (“to bear”). Hence, an aquifer is a water-bearing. The suffix -clade of aquiclude is derived from the Latin claudere (“to shut or close”). Similarly, the suffix -fuge of
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In 1890 the U.S. Geological Survey issued the dictum, reiterated in 1903 (p. 23), that: "The selection of formations shall be such that they will best meet the practical and scientific needs of the users of the map. In every case the definition of a formation in the folio text should include a statement of the important facts that led to its discrimination and of the characteristics by which it may be identified in the field, whether by geologist or layman." This should apply today to the classification, nomenclature, and mapping of hydrostratigraphic units. The need for consistent and uniform usage in classification and terminology, and therefore the promotion of unambiguous communication, is becoming greater today because of the many laws and regulations being written by nonhydrogeologists that deal with hydrogeology. One logical approach would seem to be the inclusion of hydrostratigraphic units in the North American Stratigraphic Code in order to achieve uniform standards and common procedures for these units recognized by hydrogeologists and, as importantly, their peers in the world of earth science and the general public.

Deliberations along these lines by the Committee on Hydrostratigraphic Units, Hydrogeology Division, Geological Society of America, have led to recommendations for amendments to the North American Stratigraphic Code to provide formal procedures for classifying and naming hydrostratigraphic units (Seaber, 1986). The proposed addition of hydrostratigraphic units to the 1983 code is an attempt to bring hydrogeology into harmony with the changing concepts of scientific classification and nomenclature for all types of rock units. The purpose of the addition is to promote uniform and unambiguous methods to be used in partitioning any type of body of rock into hydrostratigraphic units, based on their inherent, mappable porosity and permeability attributes.

SUMMARY

The scientific classification and nomenclature of hydrostratigraphic units closely parallels that of other material rock units. Presently, there are no available categories in any major codes of stratigraphic nomenclature that can adequately accommodate hydrostratigraphic units. The question remains open with many hydrogeologists as to whether interstices need to be a formally recognized mappable criterion, and more important, whether hydrostratigraphic mapping criteria and nomenclature can or need to be included in the North American Stratigraphic Code or in the revised International Stratigraphic Guide.

Hydrogeologic terminology is presently not uniform or consistent. Any terminology set forth should be applicable to all earth materials and all disciplines. This would assure consistent and uniform usage in classification, mapping, and terminology of hydrostratigraphic units, at least among geologists and hydrogeologists. The remaining chapters in this book illustrate the present diversity of hydrostratigraphic classification and nomenclature. Perhaps Meinzer's (1923b, p. 2) advice that "It is very useful to have definite terms to denote important scientific concepts, but it is of less consequence what these terms are, provided there is general agreement as to them" is very appropriate.

aquifuge comes from fugere ("to drive away"), while the suffix -tard of aquitard follows from the Latin tardus ("slow"). Hydrogeologists tend to use interchangeably the prefixes aqui- (Latin) and hydro- (Greek) to mean water, although these terms also mean fluid (Spilman, 1955, p. 25, 108).

The U.S. Geological Survey, since 1972 (Lohman), has used only two terms—aquifer and confining bed—for "hydrostratigraphic units." The term "confining bed" is used to collectively supplant aquiclude, aquitard, and aquifuge. The U.S. Geological Survey is presently preparing guidelines for its authors in the naming and classification of aquifers (Laney and Davidson, 1986).

A hydrostratigraphic unit, as redefined here, is a body of rock distinguished and characterized by its porosity and permeability. A hydrostratigraphic unit may occur in one or more lithostratigraphic, allostratigraphic, pedostratigraphic, or lithodemic units and is unified and delimited on the basis of its observable hydrologic characteristics that relate to its interstices. Hydrostratigraphic units are defined by the number, size, shape, arrangement, and intercollection of their interstices, and are recognized on the basis of the nature, extent, and magnitude of the interstices in any body of sedimentary, metamorphic, or igneous rock (Seaber, 1982, 1986).

Hydrogeologists have described many hydrostratigraphic units that are of broad areal extent, particularly as the results of the Regional Aquifer System Analysis (RASA) investigations of the U.S. Geological Survey (Bennett, 1979; Sun, 1986). Most of these regionally mappable units require consistency and stability of nomenclature, because they are likely to extend far beyond the locality in which they were first recognized and mapped.

In delineating hydrostratigraphic units, much discretion must be left to the field hydrogeologists, as is the case for geologists dealing with all other types of geologic units within the 1983 Code. Hydrostratigraphic units must, of course, be practical and utilitarian. Whereas establishing exact unit boundaries is up to the practicing field hydrogeologist, each unit must be mappable and should preferably be recognizable to geologist, engineer, and layman alike. Hydrostratigraphic units may vary from area to area depending on the relative permeability or porosity of the rocks, but must be reproducible and traceable.

Uncertainty presently exists in defining the classification, nature, boundaries, rank, hierarchy, and nomenclature of rocks in terms of their interstices (Seaber, 1982, 1986). This situation applies to both water-bearing and non-water-bearing deposits. One difficulty has been that the water-bearing nature of the rocks is essentially an economic and, in places, somewhat ephemeral characteristic, but is the principal focus of most ground-water investigations. The interstices are considered to be an attribute or characteristic of the rock or geologic unit that has supposedly been defined, classified, named, and mapped using other stratigraphic criteria. Hydrogeologists have, in practice, been mapping both the water and the rock for years, but the need for formalization and standardization of hydrogeologic mapping units is not yet widely accepted.
REFERENCES


Bennett, O. D., 1979, Regional ground-water systems analysis: Water Spectrum, v. 11, no. 4, p. 36–42.


Spilman, M., 1955, Medical Greek and Latin: Salt Lake City, Utah, 137 p.


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