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Future trends in stratigraphy

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Амос Салвадор — *Бъдещи тенденции в стратиграфията*. Стратиграфията е прогресирала значително от началото на века по пътя на изучаване на нарастващ брой свойства и атрибути на скалите, касаещи тяхната организация в пространството и във времето. Съществен принос в този прогрес е реализиран чрез прилагането в стратиграфията на магнитна полярност, изотопна химия, цифрова възраст. Биостратиграфията бе обогатена чрез използването на нарастващ брой фосилни групи, по-специално на микроскопски и ултрамикроскопски групи. По-доброто качество и бързото натрупване на подземни стратиграфски данни от сондажи и площни сеизмични изследвания направиха значителен принос към прогреса в стратиграфията. Ползването на компютърни системи направи възможно съхраняването, повикването и употребата на обширна стратиграфска информация.

Бъдещият прогрес в стратиграфията се очаква като следствие от продължаващия напредък в известните насоки. Никакви големи пробиви или изцяло нови насоки не могат да се предскажат. Прогрес може да се постигне само при грижливо набиране и ползуване на солидна и надеждна основна стратиграфска информация от повърхността и от дълбочини.

Introduction

During the last few years, I have been asked on several occasions what will be the future trends in stratigraphy, and what new approaches and methods may provide major advances in stratigraphic work in the years to come.

Because there is no general agreement on what does the field of stratigraphy include, it is important, before attempting to answer these questions, to define what I mean by "stratigraphy".

What is stratigraphy?

Stratigraphy is the branch of geology concerned with the description of all rock bodies forming the Earth's crust: layered as well as unlayered, composed of sedimentary, metamorphic or igneous rocks — and their organization in space and time into distinctive, useful, mappable units based on their many inherent characters, properties and attributes.

The objectives of stratigraphy, therefore, are: (1) To observe and describe the arrangement and relationships of rock bodies in space and their succession in time; (2) to organize and classify the rock bodies into distinctive, significant and useful units according to their many characters, properties and attributes (lithology, fossil content, magnetic polarity, time of formation or deposition, and many others); (3) To provide distinctive terminology for these units; (4) To fit the stratigraphic units into a determined chronology (relative and/or in term of years) preferably of worldwide significance — in other words, to date the rock units; and (5) to correlate the rock bodies from one area to another on the basis of any, several, or all of their characters and properties.

Stratigraphy should not be confused with other branches of geology. It needs to be differentiated, on the one hand, from branches of geology such as petrology, petrography sedimentology, and paleontology that deal with the study of the mineralogic composition, of the rocks, their textures and sedimentological features, their environment of formation or deposition, their chemical parameters, the classification of their contained fossils, and with many other characters, properties and attributes of the rocks as rocks and of their contained fossils as fossils. On the other hand, stratigraphy needs to be differentiated from other branches of geology that, on the basis of petrology, petrography, sedimentology, and indeed stratigraphy, deal with the reconstruction of the geologic history of the Earth — historical geology, paleogeography, etc. Stratigraphy is an objective geological discipline primarily concerned with observation, description, organization, dating, naming and correlation of rock bodies; historical geology and paleogeography are interpretative and speculative disciplines based on information from many other objective geological disciplines; stratigraphy deals with the rocks and their properties and attributes; historical geology and paleogeography interpret this and other information in terms of geologic history, in term of events, or in terms of reconstructed past geographic configuration.

Stratigraphy is a fundamental geological discipline, perhaps the most essential in reconstructing the geologic history of the Earth. Without a sound stratigraphic foundation, attempts to interpret past geological events will be futile.

With stratigraphy defined in this way, we may want next to review the past progress of stratigraphy, and the trends in stratigraphic work in recent times. Being aware of past trends and fields of progress may prove to be effective in attempting to predict their projection into the future.

Past trends and progress in stratigraphic work

During the last three or four decades, stratigraphic work has progressed through the study of an increasing number of the characters and properties of the rocks in order to describe, organize, date and correlate them and by integrating as many of these properties as are available and are necessary to arrive at the best interpretation of the local, regional or worldwide stratigraphy.

While at the beginning of this century, lithology and the contained fossils were the main, if not the only, tools of surface stratigraphy, a number of extremely powerful and useful approaches have been introduced since then: paleomagnetism (specially magnetic polarity determinations), chemical analysis (particularly the use of oxygen, carbon and strontium isotopes), relationships to breaks in the sedimentary sequence either due to eustatic sea-level changes or to tectonic events ("sequence stratigraphy", "event stratigraphy", recognition of unconformity-bounded units).

In the last few decades, stratigraphers have witnessed the progressive increase in the use of quantitative approaches, particularly statistical methods. This trend has benefited to a certain extent some stratigraphic tasks — correlation, for instance — but it also has created some potential dangers: very sophisticated quantitative methods have been applied to certain data sets without verifying their validity and accuracy or without taking into consideration if the chosen data are representative of the stratigraphic character of the area under study. The results, inspite of the precision of the mathematical technique, have been in many of these cases entirely erroneous. Quantitative approaches to stratigraphy are only as valid as is the basic data used, a fact all too often forgotten. As in all computational exercises, if garbage goes in, garbage comes out; and garbage even if camouflaged by fancy statistics is still garbage.

(How representative of the stratigraphic conditions of an area is a data set used in stratigraphic work is important not only in quantitative approaches and methods but in any kind of stratigraphic undertaking. The results are only as representative as is the data set used.)

Significant advances have also been made in biostratigraphy since the beginning of the century. Most important, probably, is the increasing use of more and different fossil groups, in particular of many microscopic and ultramicroscopic forms. These very small forms allow, in the first place, better likelihood of recovery and, in addition, permit the use of smaller samples, primarily drill cuttings. They also make possible the successful application of statistical methods that, while applicable to all fossil forms, are particularly suitable in biostratigraphic work when using very small fossil forms that usually occur in much larger numbers. Determination of the variations within species, for example, is an important new trend in biostratigraphy which has been made possible by quantitative methods. During the last three decades, the increasing use of microscopic, short-range planktonic forms has proved invaluable in establishing age-diagnostic biostratigraphic classification and correlation of marine sequences; nonmarine sediments have been more successfully dated and correlated through the study of their contained fossil spores, pollen, diatoms and ostracods.

Cooperation between biochemists and paleontologists using DNA techniques has resulted in the better understanding of phylogenetic relationships between living and fossil taxa.

Also important has been the increasing use of fossils not only to date the rocks in which they are found, but also to contribute to the establishment of the distribution of the environments in which the rocks were formed or deposited.

Numerical dating of rock bodies, in thousands or millions of years, by means of isotopic methods has added in the last few decades a new dimension to stratigraphy. Notable improvements in instrumentation and the use of an increasing number of isotopes have made possible to determine the numerical age of rocks with increasing accuracy and by means of a growing number of methods. Being able to more accurately date numerically rock bodies of more varied lithologic composition and origin is certainly a trend which has contributed to the precision of stratigraphic work. In addition, the trend toward the rapidly expanding use of numerical dating, has brought into proper focus the potential importance of igneous and metamorphic rocks in stratigraphy.

In the study of the subsurface, the quality and accuracy of the stratigraphic information has progressively improved by the development and use of better sampling devices and more informative wireline logs (electric, radioactive, sonic, density, etc.). Furthermore, the amount of subsurface stratigraphic information has grown immensely. Hundreds of thousands of wells have been drilled in most of the sedimentary basins of the world, first on land, then in the offshore shallow-water shelves of many continents; more recently, significant advances in drilling technology have made possible to extend drilling to the deepest parts of the oceans providing stratigraphic information never available before. Unlike most surface sections, which usually contain covered intervals, subsurface stratigraphic information is generally continuous, without gaps. This large volume of increasingly better and more widespread subsurface information has become essential in stratigraphic work and has provided new dimensions to the study of the geologic history of the earth, dimensions entirely unavailable to the stratigraphers at the turn of the century.

Knowledge of the subsurface stratigraphy has also been improved remarkably by information from reflection seismic profiles. For a number of years now, stratigraphers have realized that high-quality, high-resolution modern seismic reflection profiles can provide a representation of a continuous stratigraphic section thousands of meters deep and many tens or hundreds of kilometers in length. When properly processed on the basis of accurate velocity information, and when properly calibrated and tied to wells or outcrops, they can be an extremely sophisticated and useful stratigraphic tool-on land, in the continental shelves and in the deep sea. Seismic profiles have proved to be invaluable in the study of the sedimentary section of many basins in the world, particularly in the case of basins where most of the sediments forming the stratigraphic column do not crop out around the rim of the basin, where the section changes from the rims to the center of the basin, or where no information (or only very limited information) from bore holes is available. This is especially true in the case of many of the extensive offshore basins of the world. Seismic profiles, too, have contributed immeasurably in correlation within basins, either between bore holes or between bore holes and outcrops, and in determining the geometry and continuity of rock bodies. They are most useful in establishing stratigraphic relationships (unconformities, for instance), particularly those of a subtle nature difficult to detect through the study of only outcrops or subsurface sections. Seismic reflection character also can be, and has been, used successfully in interpreting the lithologic composition, fluid content, and other properties of the rocks.

A young but vigorous discipline, the so-called "seismic stratigraphy" has opened a new and extremely fertile approach to stratigraphy. It has to be remembered, however, that the information supplied by reflection seismic profiles is not information observed and recorded in the rocks; it is only a graphic (or electronic) representation of remote measurements of a certain physical property of the rocks. Rock types are only identified broadly and by inference. But if reflectors can be identified as corresponding to certain stratigraphic units (lithostratigraphic, chronostratigraphic, etc.), these reflectors can be useful in extending and mapping the units in question. Information from seismic profiles, in other words, is particularly useful and significant when integrated with other types of subsurface stratigraphic data. Such an integration of all subsurface information has greatly improved the knowledge of sedimentary basins throughout the world.

The large volume of stratigraphic information that has accumulated, at increasing rates, in the last few decades — surface, as well as subsurface information, geophysical as well as geological — and that will continue to accumulate probably at yet increasing rates, has created problems that have required new procedural approaches: how to store and manage the vast amount of stratigraphic data so it can be used and integrated. If the collected data cannot be properly assembled and used it is of little or no value. The answer, of course, has been the use of computerized storage and retrieval systems and of procedures to integrate, interpret and display the data. Computerized mapping, contouring and construction of cross sections and block diagrams, for example, has made possible stratigraphic approaches not attempted before due, among other reasons, to lack of time or manpower.

This brief review of the past trends and of the progress made in stratigraphic work during the last few decades makes somewhat more credible, perhaps, an attempt to predict the future trends and new frontiers of stratigraphy.

Euture trends in stratigraphy

Future progress in stratigraphy is expected to result from continuing advances along the same directions responsible for the progress during the last few decades. No future major breakthrough, no entirely new approach in stratigraphic work can be predicted at this time. Future progress in dating and correlating rock bodies is expected to result from gradual improvements and refinements made across a broad front. No one approach or aspect, by itself, will result in a substantial advance. Several together will make important contributions. These improvements will result from continuing progress in biostratigraphy, in magnetostratigraphy, as well as in isotopic dating methods, and in the increasing diversity and accuracy of geophysical information.

Much new and important information will become available from the study of parts of the world only imperfectly known today, and perhaps most importantly, from the drilling of wells in regions and to depths about whose stratigraphic sequences little or no information is now available.

The trend toward the expanding use of computerized systems to store, retrieve and use the rapidly accumulating volume of stratigraphic data will inevitably become increasingly important in the future, a more and more effective aid to stratigraphic work. Quantitative approaches will definitely contribute to the progress of stratigraphy.

The future progress of stratigraphy along these trends, taking advantage of the many new tools and approaches now available and of those to be developed in the future, will only be achieved, however, if efforts are made to obtain and use sound basic stratigraphic data. To realize its full potential, stratigraphic work should be solidly grounded in dependable field work: detailed field or subsurface mapping, careful measuring of surface sections, collection of representative and accurately located samples, thorough study of subsurface material. Without such reliable basic data, no progress will be possible, little will be accomplished. The most imaginative and thorough integration of stratigraphic data, the most advanced instruments and the most rigorous quantitative methodologies are useless and even misleading if the basic field data is not of the highest quality. And, as previously mentioned, without a firm stratigraphic foundation, attempts to interpret past geological events will be futile.

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