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GEOSYNCLINES
Concept and Place Within Plate Tectonics

Edited by

F. L. SCHWAB

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F. L. SCHWAB

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SERIES EDITOR'S FOREWORD

The philosophy behind the Benchmark Papers in Geology is one of collection, sifting, and rediffusion. Scientific literature today is so vast, so dispersed, and, in the case of old papers, so inaccessible for readers not in the immediate neighborhood of major libraries that much valuable information has been ignored by default. It has become just so difficult, or so time consuming, to search out the key papers in any basic area of research that one can hardly blame a busy person for skimping on some of his or her "homework."

This series of volumes has been devised, therefore, as a practical solution to this critical problem. The geologist, perhaps even more than any other scientist, often suffers from twin difficulties—isolation from central library resources and immensely diffused sources of material. New colleges and industrial libraries simply cannot afford to purchase complete runs of all the world's earth science literature. Specialists simply cannot locate reprints or copies of all their principal reference materials. So it is that we are now making a concerted effort to gather into single volumes the critical materials needed to reconstruct the background of any and every major topic of our discipline.

We are interpreting "geology" in its broadest sense: the fundamental science of the planet Earth, its materials, its history, and its dynamics. Because of training in "earthy" materials, we also take in astrogeology, the corresponding aspect of the planetary sciences. Besides the classical core disciplines such as mineralogy, petrology, structure, geomorphology, paleontology, and stratigraphy, we embrace the newer fields of geophysics and geochemistry, applied also to oceanography, geochronology, and paleoecology. We recognize the work of the mining geologists, the petroleum geologists, the hydrologists, and the engineering and environmental geologists. Each specialist needs a working library. We are endeavoring to make the task of compiling such a library a little easier.

Each volume in the series contains an introduction prepared by a specialist (the volume editor)—a "state of the art" opening or a summary of the object and content of the volume. The articles, usually some twenty to fifty reproduced either in their entirety or in significant extracts, are selected in an attempt to cover the field, from the key papers of the last century to fairly recent work. Where the original works are in foreign languages, we have endeavored to locate or commission translations. Geologists, because of their global subject, are often acutely aware of the oneness of our world. The selections cannot therefore be restricted to any one country, and whenever possible an attempt is made to scan the world literature.

To each article, or group of kindred articles, some sort of "highlight commentary" is usually supplied by the volume editor. This commentary should serve to bring that article into historical perspective and to emphasize its particular role in the growth of the field. References, or citations, wherever possible, will be reproduced in their entirety—for by this means the observant reader can assess the background material available to that particular author, or, if desired, he or she too can double check the earlier sources.

A "benchmark," in surveyor's terminology, is an established point on the ground that is recorded on our maps. It is usually anything that is a vantage point, from a modest hill to a mountain peak. From the historical viewpoint, these benchmarks are the bricks of our scientific edifice.

RHODES W. FAIRBRIDGE

PREFACE

Geosynclinal theory is a comprehensive scheme that genetically relates regionally extensive, subsiding segments of the earth's crust that fill with sediment *and* the intensely deformed, metamorphosed, and intruded fold belts found around the globe. The concept was first postulated by an American geologist, James Hall, in the 1850s. He pointed out the apparent causal relationship between folded mountain belts and the thickness of the sedimentary rock succession of which they were composed. Shortly thereafter, James Dwight Dana of Yale University attributed the deformation of the thick sediment fill of these *geosynclinals* to the effects of lateral horizontal compression occurring on a global scale. Dana argued that such global compression was essentially localized at the site of the linear geosynclinal. For a century following its initial postulation, geosynclinal theory has probably remained the single most important unifying conceptual scheme in the geological sciences, despite serious differences of opinion as to what the concept actually entails.

In the 1960s and 1970s, geosynclinal theory has been overtaken and largely incorporated into plate tectonics theory, a framework of conceptual ideas or geological paradigm that although rooted in the suggestions of several earlier workers, has now emerged to explain the present-day tectonic activity of the earth: the global network of earthquake belts and volcanic activity, the physiographic features of the ocean basins, and the origin and distribution of modern mobile belts. Plate tectonics theory relates all of these present-day tectonic phenomena to the movement of internally rigid plates of the lithosphere relative to one another. Much of the tectonic activity visible today occurs coincident with the margins of individual plates, although mid-plate disturbances are also observed.

The forty-six papers selected for this volume trace the historical development of the geosynclinal concept from its birth in the middle of the nineteenth century until the present, emphasizing how the concept has been constantly reshaped and broadened in order to conform to changing ideas and new observational data. This historical reassessment of classical geosynclinal theory is particularly appropriate at this point in time because of the growing evidence and consensus within the geological community that plate tectonics mechanisms also operated in the geological past to produce ancient mountain systems, at least as far back as the Proterozoic and perhaps even as early as during Archean time.

The papers included in this volume cover a period from 1859 to 1977. These papers make it clear that during most of this time interval, what was inferred and included within the context of classical geosynclinal theory depended largely on personal biases conditioned by geological and geographical perspective. Nevertheless, geosynclinal theory proved flexible enough to tolerate widespread differences of interpretation, and papers explaining ancient mobile belts in terms of geosynclinal evolution dominate the geological literature throughout the late nineteenth century and well into the twentieth. It is particularly appropriate to examine the extent to which this classical theory can be retained within a geological community now dominated by the paradigm of "the new global tectonics."

I am happy to acknowledge the constructive suggestions I have received from Rhodes Fairbridge, series editor of the Benchmark Papers in Geology series. I am also grateful to Susie White and Peggy Riethmiller for secretarial assistance, and to my wife Claudia who ably provided general help and encouragement.

F. L. SCHWAB

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INTRODUCTION

The first geologist to formally propose that a direct *causal* relationship exists between thick linear belts of sediment and the formation of mountain systems was James Hall (1859, 1883). Ever since this view was initiated in the middle of the nineteenth century, most geologists have used "geosynclinal theory" to explain the origin of mountain systems, the accretion of continents, and the distribution in time and space of thick lithological assemblages of sediment.

Like most of his contemporaries, Hall subscribed to the view that mountains were essentially produced by vertical uplift and subsidence, and he accepted the then popular notion that the earth's interior was pliable and consequently readily responsive to gravitational loading. Such an assumption was apparent in the actual mechanism invoked by Hall to create mountains. Downwarping of the earth's crust was assumed to have occurred in response to the accumulation of a thick mass of sediment. Subsequent crumpling of the layers of sediment produced local increases in elevation. However, Hall implied that *most* of the elevation of a mountain chain was due to the buoyancy of the sediment-thickened crustal segment; he directly stated that thicker accumulations of sediment produced correspondingly higher mountain ranges. This statement represents one of the earliest assertions of the existence of isostasy, although the term was not to be introduced until some three decades later (by Dutton, 1889).

Although Hall's arguments genetically relating linear fold belts to precursory sediment-filled troughs were convincing, many geologists did not agree with the mechanisms invoked by Hall to downwarp, deform, and uplift the geosynclinal belt. Consequently, they soon began to modify the original geosynclinal concept, asserting that geosynclines were produced by the effects of lateral global compression localized along elongate zones of crustal weakness. This modification of geosynclinal theory, the first of many to occur over the course of the next hundred years, was crafted largely by James Dana (1866; 1873) in the 1860s and 1870s. Dana also focused attention on the position of geosynclines relative to the continental blocks and ocean basins, on the possible role of geosynclines in the growth of continental crust, and on the relative importance of various kinds of geosynclinal source areas.

Early differences between the opinions of Hall and Dana touched off decades of disagreement regarding the relative importance of simple lateral compression versus vertical uplift due to isostasy in producing mountainous topography. This debate, essentially an argument over the internal strength of the crust and its susceptibility to both vertical uplift and subsidence as well as horizontal compression, continued well into the twentieth century. At times, the original concept of the geosyncline was almost completely overshadowed or modified beyond recognition. Nevertheless, again and again geologists returned to the basic premises on which geosynclinal theory was based, reshaping and redefining the concept to best suit their own prejudices or type examples. The generous flexibility allowed within the constraints of geosynclinal theory would nearly be its undoing.

This volume is a collection of classic papers tracing the development of geosynclinal theory from its birth (Part I) to the present time. These papers serve to illustrate that the concept, while useful in a variety of ways as a means of explaining mountain belts, has proved to be an elusive, almost illusionary, difficult-to-define conceptual scheme. Declarations of the definitive characteristics attributed to geosynclines have almost always been with reference to specific examples. Only in the past two decades, with the advent of the theories of the new global tectonics, has it become clear that a wide variety of ancient geosynclines existed, each analogous to the various modern types of ocean basins and continental margins.

Until 1960, the geosynclinal concept produced almost as much confusion as clarity. The geosynclinal characteristic most consistently (but not always) incorporated into the scheme over the past one hundred years is the relationship originally postulated by Hall: the coincidence between mountain belts and linear tracts of thick sedimentary rocks. Otherwise, all aspects of what constitutes a geosyncline have been continually reshaped and redefined, particularly the causal mechanisms invoked to produce and deform geosynclinal basins, the classification schemes used to differentiate among geosynclinal varieties, the depositional environments thought to typify geosynclinal sedimentation, and the position of geosynclinal belts relative to continental blocks and ocean basins.

For example, European geologists (notably in France, Germany, and Switzerland) had enthusiastically embraced geosynclinal theory before the turn of the century, but eventually, led by Haug (1900), they came to fundamentally disagree with the notions of Hall and Dana regarding the shallow-water nature of geosynclinal sediments and the position of geosynclines relative to the continental blocks (Part II). The Alpine belt, unlike the Appalachians, did not straddle a continental margin, nor did it seem to have a floor of continental (sialic) crust. Furthermore, the Europeans perceived geosynclinal development as an orderly process, attested to by systematic lateral and vertical distributions in the sedimentary and volcanic rock infilling (Part III). This view was enthusiastically adopted by American geologists who began to consider the geosynclinal mechanism as deterministic: the geosyncline is the father of the mountain. They believed that geosynclines *necessarily* produced deformed mountain systems and in the process followed a nearly identical, predetermined course of development. Later acceptance of plate tectonics theory has strongly modified this notion and has also explained the many departures from any uniform evolutionary scheme.

Much of the historical development of geosynclinal theory as a unifying theme in geology has centered upon attempts to more clearly define and differentiate the various types of geosynclinal basins. These efforts have resulted in a vast array of classification schemes and terminology, intentionally broad enough to encompass all possible variations from the general case, yet unfortunately too complex to be easily applicable and analytically useful (Part IV). A lively debate over the various kinds of clastic source areas for geosynclinal fill also stemmed from these efforts.

Other workers were less concerned with clåssification, terminology, and the characterization of individual varieties of geosynclines, considering instead the mechanisms responsible for producing geosynclines in general and for causing their eventual conversion into deformed mountain belts. Some of these early attempts (Argand, 1916, 1920, 1922; Wegener, 1912, 1922, 1966; Holmes, 1931, 1945) were remarkably "modern" in the sense that they interpreted geosynclinal evolution in terms of global mechanisms not unlike those incorporated into modern plate tectonics theory: continental drift, sea-floor spreading, subcrustal convection, and the existence of ocean basins that periodically open and close thus deforming continental margin, trench, and abyssal plain sediments into mobile belts (Part V).

Despite such perceptive foresight, geosynclinal theory has also generated considerable confusion and controversy, and by 1950, the concept had raised as many questions as it had resolved (Part VI). However, just as this general atmosphere of pessimism and disenchantment began to descend over conventional geosynclinal theory, renewed interest in continental drift was generated by the discovery of sea-floor spreading and strengthened by new revelations about paleomagnetism and observations on the physiography and geology of the modern ocean basins. These revitalized mobilist theories immediately provided an entirely different structural framework within which the classical schemes for ancient geosynclinal evolution and mountain-making might also have operated (Part VII). The varied setting of modern mobile belts demonstrates that their ancient equivalents must have been equally as diverse. Consequently, many of the problems concerning ancient mobile belts that classical geosynclinal theory was unable to resolve became understandable when classical theory was modified in light of plate theory (Part VIII). The encouraging success of these efforts led directly to numerous further attempts to better understand the structural and lithological signatures imprinted on the various modern mobile belts. Analytical keys useful for deciphering ancient geosynclinal mobile belts could now be effectively linked to modern, actualistic analogues (Part IX). Again, by using the present as a key to the past, traditional Lyellian and Huttonian philosophy was triumphant.

No problem in geology has been more fascinating or challenging than that of explaining the origin and evolution of the globe's major mountain systems. The continued viability of the geosynclinal explanation for mountain building over the course of the last century has now been extended by the incorporation of conventional geosynclinal theory within the context of modern plate tectonics theory, and probably represents the single most exciting revolution in geological thinking (Part X).

Plate tectonics theory requires that geologists now view geosynclinal origin and evolution from a radically different analytical perspective than that initially used by Hall and Dana. Not only do the depositional, tectonic, and paleogeographical settings for geosynclines vary greatly from one another, they also contrast decidedly with the standardized models originally suggested by

Haug, Hall, Stille, Kay, and others. Plate theory indicates that geosynclines and their component parts can be juxtaposed spatially and temporally to produce an almost endless variety of mobile belts. The resultant complex organization visible in ancient mobile belts stands in stark contrast to the simplistic, systematic characterization once applied universally to geosynclines within the constraints of a generalized geotectonic cycle.

Because our models of what ancient geosynclines represent and where their modern analogues now exist have changed, it is also necessary to modify the terminology and classification schemes applied to geosynclines. This volume demonstrates that geosynclinal theory repeatedly has been flexible enough to be adopted to new analytical models of the earth. The changes made imperative by the universal adoption of plate tectonics mechanisms are neither cosmetic or apocalyptic, although they are probably more fundamental in nature than any of the earlier modifications. The basic aspects of geosynclinal theory—the single most unifying concept in geology—can certainly be accomodated within the premises of sea-floor spreading, continental drift, and plate tectonics. For the future, the concept will probably continue to be reshaped to conform to changing modern perceptions.

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