THE GEOLOGIC HISTORY OF HARTLAND, CONNECTICUT AS DEDUCED FROM BEDROCK AND SURFICIAL FEATURES FROM THE BOTTOM UP

Prepared by
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for
Presentation to the

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THE GEOLOGIC HISTORY OF HARTLAND, CONNECTICUT AS DEDUCED FROM BEDROCK AND SURFICIAL FEATURES FROM THE BOTTOM UP

It is a pleasure to be here this evening to talk with you about my favorite topic - GEOLOGY. I thank all of you for the invitation and the help with logistics. The presentation this evening will be a view of our geologic history from the bottom up.

Deep time:

We hear a lot about the BIG BANG, the beginning of it all and there are some very searching philosophical inquiries into what was there before the beginning of the universe. Though numerous discussions, largely centered around the introductory words of Genesis, have been written throughout history by numerous scholars as St. Thomas Aquinas (Book 16) and later religious scholars and philosophers. Unfortunately they are beyond the scope of this presentation. We will look back at the beginning of the universe about 13.6 billion years age from our position long after the Big Bang. For us time and space, matter and energy were throughout our view just as they are now.

The general model for the origin of the Earth was first formally proposed by LaPlace in his *Systeme du monde* (1796) and his condensation theory served as the model will into modern time. The notion that the earth "condensed" from a whirling mass of gas (dispersed matter) explains the orbital characteristics of planets and existence of an earth crust, mantle and core. It accommodates out observations and their implications. Though various dates have been proposed for the "age" of the earth, most have been between 4.7 and 5.5 billion years (Ga). It is interesting that the radiometric age of meteorites is between 4.5 and 4.7 Ga based on uranium-lead, potassium-argon and rubidium-strontium methods and lunar samples average 4.66 Ga. Observations in the Stillwater Igneous complex in Montana indicate a magnet signature about 2.75 Ga old implying that the iron-nickel core is at least that old. Every indication is that stratification of the earth was essentially established by 2.75 billion years ago.

Crustal formation is assumed to have followed stratification in only a few million years or so but is very difficult to establish with certainty. Over the centuries of written records the age of the earth has been determined by numerous methods and oddly enough was determined by Indian scholars in fifth century A.D. to be about 4.3 billion years (Teresi, 2002). With all of our science and technology today's best estimates for the age of the earth range around 4.6 billion years.

Habitability of the earth is only possible after the formation of a solid, rocky crust and is intimately associated with the evolution of the atmosphere. Some laboratory experiments may be useful in understanding the origin(s) of life as we know it (ofter referred to as carbon based life) and thus describing conditions for an habitable earth.

In 1936 the Russian biochemist A. I. Oparin proposed the theory that the early atmosphere of the earth was strongly reducing and comprised of methane and ammonia. Oxygen and carbon dioxide were conspicuously missing. The "organic soup" that formed in those conditions endured and through chemical combination reproduction was implied.

In 1953 Stanley Miller produced organic molecules from the chemistry suggested by Oprin by passing an electric spark through a mixture of ammonia, methane, water vapor and hydrogen. Amino acids, the building blocks of life were produced. Was lightning the spark of life in the early atmosphere?

In 1957 Philip Abelson added carbon monoxide, carbon dioxide and nitrogen to the mixture and produced all the amino acids necessary for life. Nevertheless, none of this actually produced life in the test tube but, it did tell geologists what to look for in the rocks.

The oldest physical remains that geologists are willing to call fossils of living forms are about 3.4 billion years old. The implications of this discovery are that the atmosphere enabled life (habitation) about a billion years after formation of the earth and that the oceans (condensed water) existed at that time. From the condensation of interstellar gas to form our planet to the first habitable conditions was amazingly rapid. It is also reasonable to assume that "continents and oceans" existed and behaved then much as today. The history of the ancient life that developed over that period is summarized in a diagram provided.

Geologic time:

Although the term "geologic time" is not formally defined, a distinction is made here with deep time in that geologic time is determined from direct observations of geologic specimens such as rocks and fossils. The concept of geologic time is fairly recent having developed in the early 1800s when geology developed as a science from "natural science" itself having developed from "natural philosophy" half a century earlier. The recognition that fossils were in fact the remains of organisms that lived in ancient times, some of which were not represented by modern flora and fauna, made necessary the extension of geologic time from a few thousand to at least a few million years necessary. The scope of time was even measured in myth. Hendrick Van Loon measured time in the following medieval myth:

> ***High up in the North in the land called Svithjod, there stands a rock. It is a hundred miles high and a hundred miles wide. Once every thousand years a little bird comes to the rock to sharpen its beak.***
>
> ***When the rock has thus been worn away, then a single day of eternity will have gone by.***

However well established and accepted by scholars, the time frame of geologic time remains mind boggling.

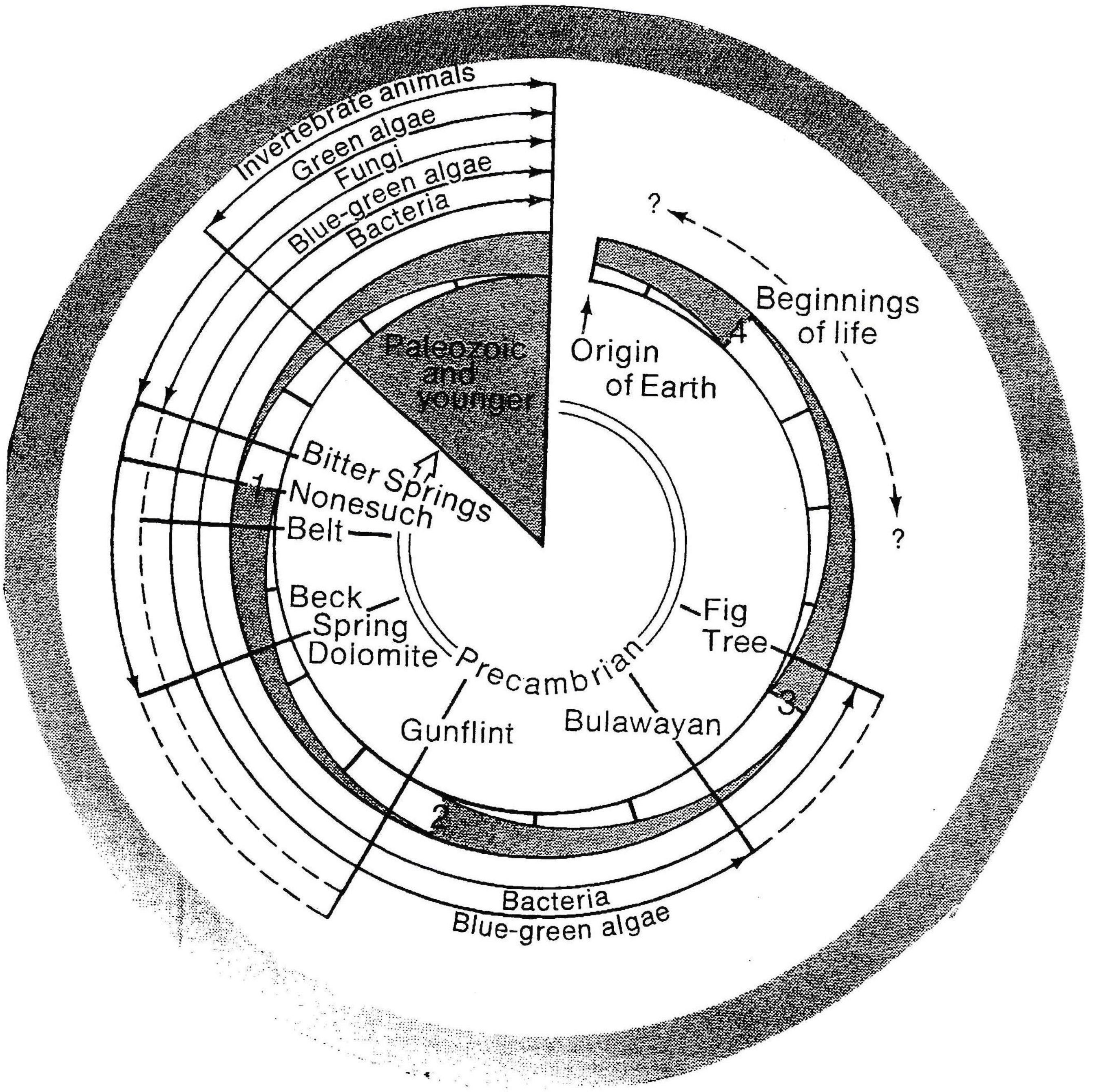
We will start with the beginnings of earth history about 4.6 billion years ago and end with the landforms remaining after melting of the last glacier about 10,000 years ago in this area. The time span involved in this discussion is enormous and almost impossible to grasp because we have no experience against which to measure it. When we speak of continental drift and the collisions that take place between and among the various crustal plates, we are talking about movements of a few inches per year. In the context of geologic time the continents are bouncing off each other leaving behind the bumps, dents and wrinkles that we call mountain ranges. Such movements are consistent with the world as we know it today (the Atlantic spreading at several inches per year) and are therefore applicable to conditions in the past. .

Although the age of the Earth is set when the skin known as the crust formed and provided a solid surface separating the molten interior from the atmosphere, when we examine the oldest rocks on the earth we never find rocks that old most likely because they have been destroyed or altered by the chemical and physical processes of weathering. Fortunately for geologists with soft bodied life forms already abundant in the world's oceans (see *Wonderful Life*, Steven Jay Gould), about 550 million years ago those creatures suddenly acquired the ability to metabolize calcareous shells which were easily preserved as fossils. The exact reason for that event is complex with interaction of out gassing from the planet, change in atmospheric chemistry and availability of shell making ingredients in sea water. Whatever the complexities of the cause, the wide distribution of abundant fossils of organisms changing over time gives the geologist exactly the device needed to characterize and correlate the strata in which they were found.

. When we examine the oldest rocks on the earth, however, geologists never find rocks composed of original crust 4.5 Ga old most likely because chemical and physical processes of weathering have destroyed or altered the original rocks. Where those processes are absent older dates should be found and indeed rocky material from meteors and moon dust yield dates to almost 4.6 billion years before present. It appears that our date of 4.6 Billion years for the age of the earth is confirmed.

About 3.2 to 3.4 Ga ago, indications are that life had begun in the sea with the appearance of bacteria and blue-green algae. About 2 Ga ago some more complex froms appeared but most of the organisms were chitenous. Siliceous, or soft-bodied. Fortunately for the geologist, soft-bodied life forms, already abundant in the world's oceans (see *Wonderful Life*, Steven Jay Gould), suddenly acquired the ability to metabolize calcareous

PRECAMBRIAM LIFE



After Kummel, Bernhard (1961) History of the Earth, p.51

shells which were easily preserved as fossils. Suddenly, about 550 million years ago there were fossils everywhere! The exact reason for that event is complex with interaction of out gassing from the planet, change in atmospheric chemistry and availability of shell making ingredients in seawater. Whatever the complexities of the cause, the wide distribution of abundant fossils of organisms changing over time gave the geologist exactly the device needed to characterize and correlate the strata in which they were found. With the help of the fossils as markers for the various strata, geologists developed a detailed history for the earth covering the last 550 million years. Though what is known about the post-fossil history can be extrapolated to the pre-fossil history, we are going to be concerned only with the last 550 million years of earth history at this time.

Phanerozoic time:

Geologists have divided the last 550 million years into three great eras reflecting the broadest generalizations about life forms; those have been divided into periods and they in turn into epochs etc. A Geologic Time Table follows. I have added information about the major mountain building times to the chart to give it context in North America.

Hartland:

Here in Hartland, today, our bedrock dates from the Paleozoic but the strata represented here are generally devoid of fossils. The strata may have once contained abundant fossils but they could not have survived the high temperatures and pressures of metamorphism. The rocks which are represented today as schist and gneiss are recrystallized sediments laid down in lower Paleozoic time some 500 million years ago. Much of what we know about the age of the rocks in Hartland is based on inferences from fossils found elsewhere and/or from radiometric dates obtained by isotope analysis. The use of fossils as a sole dating method must be used with caution and generally we can not simply pick up a fossil and give its age (age of the rock in which it is found) without consideration of context. There is an amusing story well known ay all geologists to point out the fallacy. You can substitute for X any geologist you wish to impugn.

An above average student, actually listening to the presentation on fossils and their use in dating rocks being delivered by Professor X suddenly found himself perplexed. Raising his hand energetically with confusion in his eyes he stated "I'm confused here. How did you say we determine the age of the rocks?" "From the fossils", the professor replied. "And how do we determine the age of the fossils? the student continued. Without pause the professor replied "Why, from the rocks!"

To a large extent, the role of geology is to present a story that is generally believable and consistent with the facts as they are developed by technical investigation in the sciences. To tell that story geologists use context as determined from a wide variety of disciplines like structural geology which involves the geometry of rocks (on the small scale called petrofabrics), geochemistry, petrography, mineralogy, etc. All the observations must be accommodated in the story.

The Bedrock History

We do not generally think of Connecticut as part of the Appalachians, but we share a similar tectonic history. A great trough extended from the Gaspe to the Gulf of Mexico through most of Paleozoic time. During that period sediments accumulated in the trough which slowly sank to accommodate their growing volume. The trough is known as the Eastern or Appalachian Geosyncline. The Appalachians proper are the result of a major mountain building event in the upper Paleozoic (Permian) which was the collimation of a series of earlier events associated with the geosynclinal belt(see the attached Geologic Time Table with tectonic events imposed).. Three major events altered the Eastern Geosyncline during the Paleozoic:

The **Taconic event** took place in the upper Ordovician about 360 million years ago. The sediments were folded, faulted and uplifted over about half of New England and some feel that the resulting mountains were truly majestic, rivaling the modern Rockies.

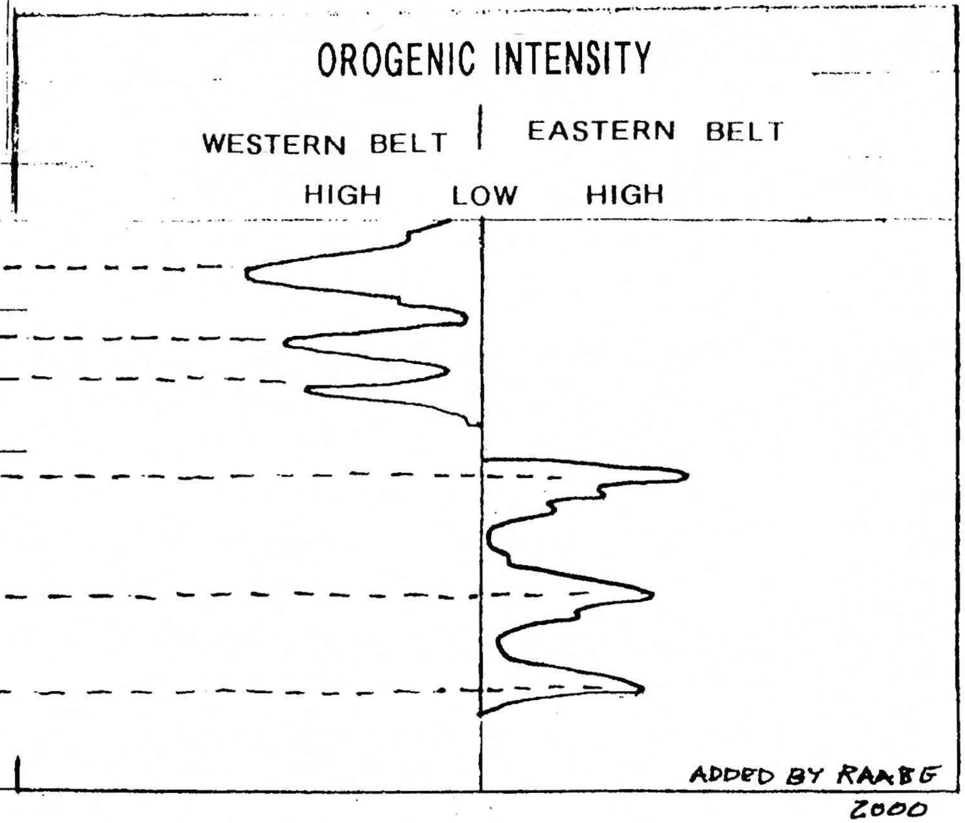
GEOLOGIC TIME AND ASSOCIATED OROGENESIS

TABLE 26.2. THE GEOLOGIC TIME SCALE*

Era	Period		Duration m.y.	Age m.y.	Orogenies (Orogenic Event)
CENOZOIC	Quaternary		2.5	2.5	
	Tertiary		62.5	65	Cascadian
MESOZOIC	Cretaceous		71	136	Laramian
	Jurassic		54	190	Nevadian
	Triassic		35	225	
PALEOZOIC	Permian		55	280	Appalachian (Hercynian)
	Carbon-iferous	Pennsylvanian	45	325	
		Mississippian	20	345	
	Devonian		50	395	Acadian (Caledonian)
	Silurian		35	430	
	Ordovician		70	500	Taconian
	Cambrian		70	570	

		Duration b.y.	Age b.y.	
PRECAMBRIAN or PROTOZOIC	Upper Precambrian	0.3–0.4	0.9–1.0	Grenville
	Middle Precambrian	0.6–0.8	1.6–1.7	Hudsonian
		0.7–0.9	2.4–2.5	Kenoran
	Lower Precambrian	0.9–1.0		
	Oldest dated rocks		3.4±0.1	
	Earth accretion completed		4.6–4.7	
	Age of universe		7–9?	

* Data sources: D. Eicher (1968), *Geologic Time*, Englewood Cliffs, N.J., Prentice-Hall, and paper; M. Kay and E. H. Colbert (1965), *Stratigraphy and Earth History*, New York, Wiley, p. 74.



In the upper Devonian, about 265 million years ago and some 90-95 million years after the Taconic event, the Eastern Geosyncline was disturbed again by a largely intrusive event. The **Acadian event** was a "wet" event in which numerous granitic plutons were intruded into the New England portion of the Appalachian belt especially in New Hampshire and Maine. The White Mountains in New Hampshire and the Cadillac Mountains are typical examples of the massive granites associated with this event.

Finally in the Permian, about 180 million years ago the Appalachian Mountains were formed in an orogenic event that lasted nearly 50 million years. Unlike the earlier events, the **Appalachian event** involved the rocks in the southern as well as the northern portion of the Eastern belt. The event began with folding and uplift in the Pennsylvanian (upper Carboniferous) period and ended with westward thrusting in the late Permian period.

Subsequent to their development as a mountain range, the Appalachians have been reduced to a nearly flat plain at least twice having been renewed in the meantime by general uplift. The nearly flat mountain tops visible as a flat skyline over much of the terrain in eastern and western Connecticut are remnants of those once low, flat surfaces. Observing these elevated plains in the field while squinting authoritatively along an outstretched hand has won the Geomorphologists the label "straight-arm geologists". The roots of mountains now exposed by time, uplift and erosion provide the geologist with a unique "worm's eye" of Connecticut geology.

Only one major event remains to complete the bedrock history of the State. About 160 million years ago, in the Triassic period, a final disturbance took place in the already closed geosyncline. Though not represented by rocks in Hartland, Triassic sediments and Mesozoic faulting set the stage for the topography underlying the low lands, which give us the spectacular view to the east from Mountain Road near the boundary with Granby. The disturbance is called the Pallisadian after the famous cliffs by that name and the distinctive red sediments associated with it are known as the Newark Series. Unlike the crystalline rocks of the Hartland highlands, the Triassic red beds are famous for dinosaur tracks, fish fossils and occasional turtles. The lava flows, sills and dikes generally referred to as trap rock yield easily accessible durable stone and aggregate for construction.

Generally the red sediments were interbedded with lava or trap rock as they accumulated in a great down faulted trench more or less in the nature of a great layer cake. As the sediments accumulated in the ditch or 'graben' , basic lava poured out and flowed over the sediments forming thick sheets. Anyone traveling east-west across central Connecticut is keenly aware of the west-facing ridges that they cross. In fact, there are rather few major east-west roads in Connecticut partially, I believe, because of the impediment to travel presented by the ridges in colonial times. Adding to the topographic effects of the lava flows, the "grain" of our topography induced by the north to south movement of active glacial ice across the area has added to the difficulty of east-west travel. (Note importance of route 44) We look at glaciation in the next section.

Stepping back from the Bedrock Geologic Map of Connecticut, one is immediately that the state can be divided into three provinces; the Eastern Highlands, the Central Lowland and the Western Highlands. These three provinces (and a portion of the Taconics in the extreme northwest corner of the state) are discussed in detail in the abundant literature on the geology of Connecticut.

The Glacial History

Glacial history is generally measured in thousands rather than millions of years and that is the case for Connecticut. In many respects the study of the glacial history is a peeling back of the plastered down remains of the glacial processes that once effected the terrain and so is worked "top down". In most cases the struggle to understand the glacial history of Connecticut is rooted in studies of deglaciation. It is the passing of the glacial epoch that results in the distribution of sand and gravel, of boulders and till and unconsolidated material that we improperly refer to as soil. The period of time when the region was under the direct influence of glacial ice is called the Pleistocene epoch (Part of the Quaternary period) and the time after glaciation is called the Holocene. Deglaciation sits at the boundary of geologic time designations just as we in this room are sitting on the boundaries of the century and the millennium. To make matters worse, the Holocene may not have come to all sites at the same time. Here in Connecticut, here in the Eastern

Upland, peat and wood samples from the bottom of the marshes date to about 10,000 years b.p. with most samples in the 5,000 to 7,000 y.b.p. range. In general, the accumulation of peat began about 11-12,000 y.b.p.. The region was probably covered with ice up to about 20,000 y.b.p.. By this simple, possibly simplistic, reasoning, the period from about 20,000 to about 5,000 years ago represents the time of deglaciation -- the boundary between a glacial and non-glacial time.

The results of deglaciation are apparent in a number of features in Hartland but none are so well known as the "Balance Rock" or the gravel esker extending from Sunset Road south to the Town line where its sinuous serpentine form gives way to a number of more or less distinct sand and gravel knolls.

Balance Rock was quite an attraction in more leisurely times when it was a common site for picnics and outdoor gatherings. The story is told that out of concern for the safety of the picnickers, though more likely driven by personal pride or a bet, an attempt was made to topple the rocking boulder from its perch on the edge of a low cliff. The attempt was apparently unsuccessful and it stands today just as it did when photographed by Lewis E. Mills (in Ransom, History of Hartland).

Unfortunately the esker is mostly gone today having been dug out for gravel. Where its gravels were either too course of too rich in fine sand and silt to make them useful, they still remain.

Though I have singled out the Balance Rock and the Esker as examples of the influence of natural features of deglaciation on Hartland there are many other significant influences of these features on our history. The upland swamps that remain from the ancient erosion surfaces mentioned above are important in providing habitat and water filtration functions. The glaciation broadened and deepened the preglacial Hartland topography and truncated the interlocking mountain spurs typical of the preglacial terrain. The result was "hanging valleys" where water falls developed. They were ideal locations for mills and Hartland had a large number of them for sawing lumber and grinding witch hazel. The ruins are still visible for any hiker's enjoyment. Evidence of water diversion from the upland streams is also evidenced by the remains of foundations and small dams. Some water was probable used of watering cattle and related farm activities but some sites have a foundation geometry typical of distilleries. These are all gifts of the glacier and have had a significant effect on the history and people of Hartland.

For those interested, there are a number of publications and papers that began in the late nineteenth century and extend to the present time. Remarkably, because the studies are based on keen observation, they remain relevant even to the present day. The basic tenant of glacial geology is that the form exists as a scientific fact and that the role of the geologist is to attach process to it through careful implication and comparison with forms and processes known in modern time. Though the specifics of interpretation may change as geologic knowledge expands, the geomorphic descriptions of the glacial forms remain valid. As an example, one can compare the Surficial Geologic Map prepared by Richard Flint in 1930 to accompany "The Glacial Geology of Connecticut", with the map prepared by Stone, *et al* as U.S. Geological Survey Open-file Rept 98-371 "Quaternary Geologic Map of Connecticut and Long Island Sound Basin". There is considerable more detail in the 1998-99 map but it is somewhat more difficult to interpret visually than the 1930 treatment by Flint. Perhaps our human perception that greater knowledge lies in greater detail is really "Heisenberg's Revenge" for we forget that the road to wisdom is almost always generalization.

SOME OF THE SCIENCE BEHIND THE STORY

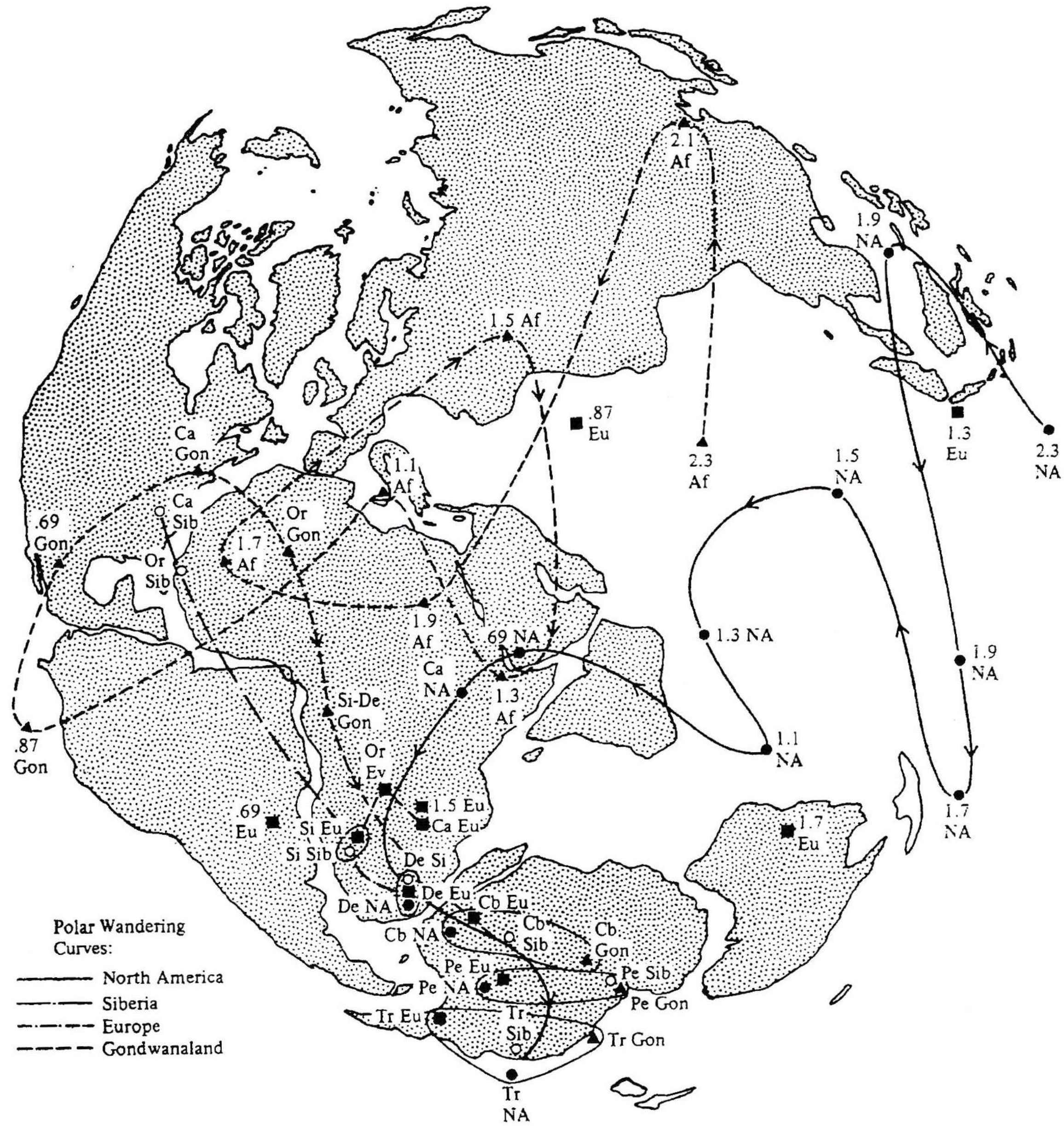
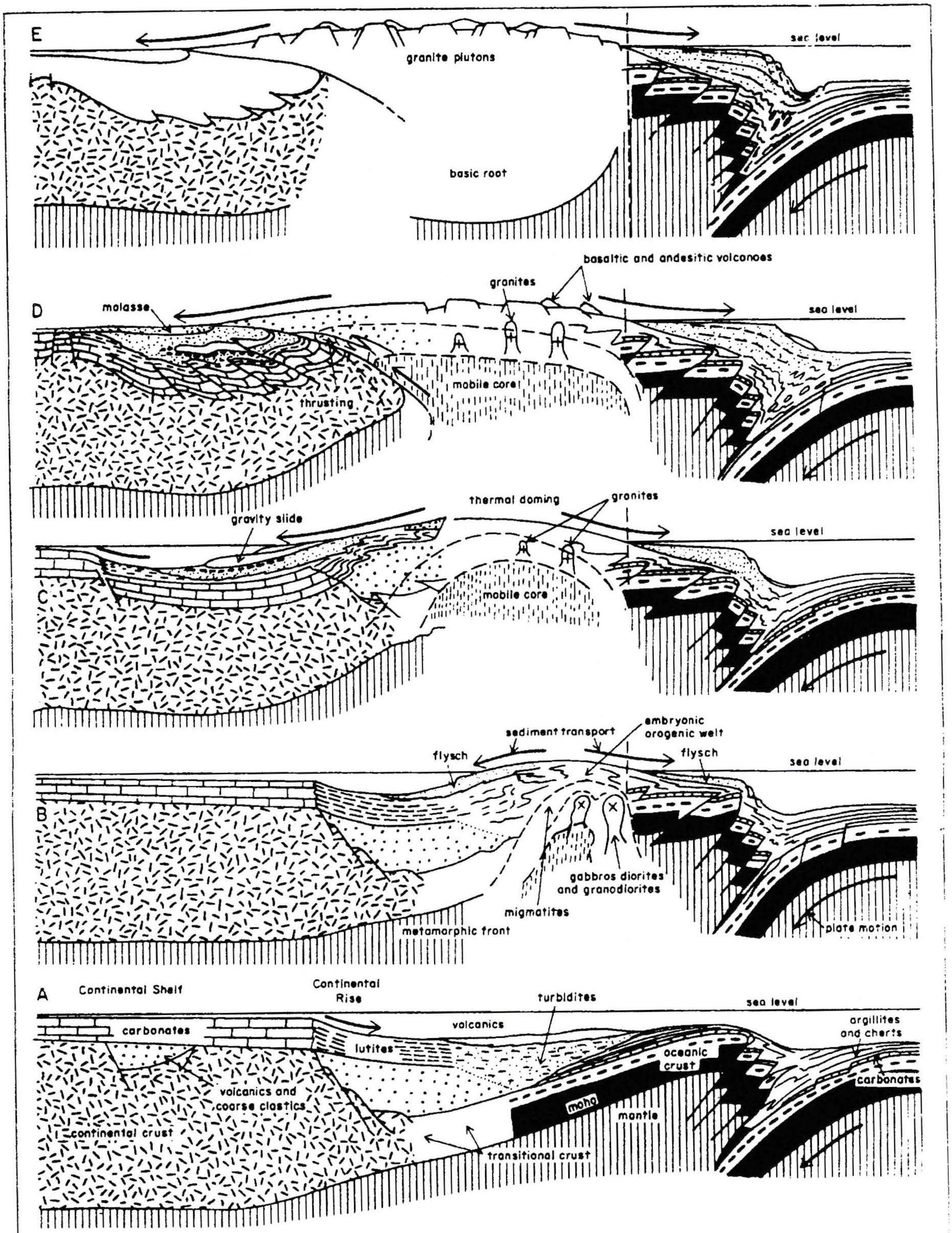


Figure 7.41 Recalculated polar wandering curves for the continents comprising Pangaea. The Precambrian paleomagnetic poles for North America and Europe are widely separated, which indicates that these continents were apart during the Precambrian. The polar wandering curves don't agree until the Ordovician, suggesting that the continents joined at that time. Poles for the Silurian through the Triassic agree rather well, indicating that the continents were not significantly separated during this interval. The Early Paleozoic curves for China and Siberia do not agree with either the North American or the European curves, which suggests that China and Siberia were separated from Europe and North America at that time. Comparison of the polar wandering curve of Gondwanaland with the polar wandering curves of the other continents indicates that Gondwanaland was separated from the other continents prior to the Carboniferous and joined to the other continents from the Carboniferous through the Triassic.

From: Seyfert, Carl K. and Leslie A. Sirkin (1973) *Earth History and Plate Tectonics*



OROGENESIS AT CONTINENTAL MARGIN

Stages in the development of a mountain range (A-E) at a continental margin driven by subduction. For the subduction to be maintained, the plate must be pushing on the continental block as the continental mass pushes back. Thus continents generally have only one active margin with energy supplied by sea floor spreading.

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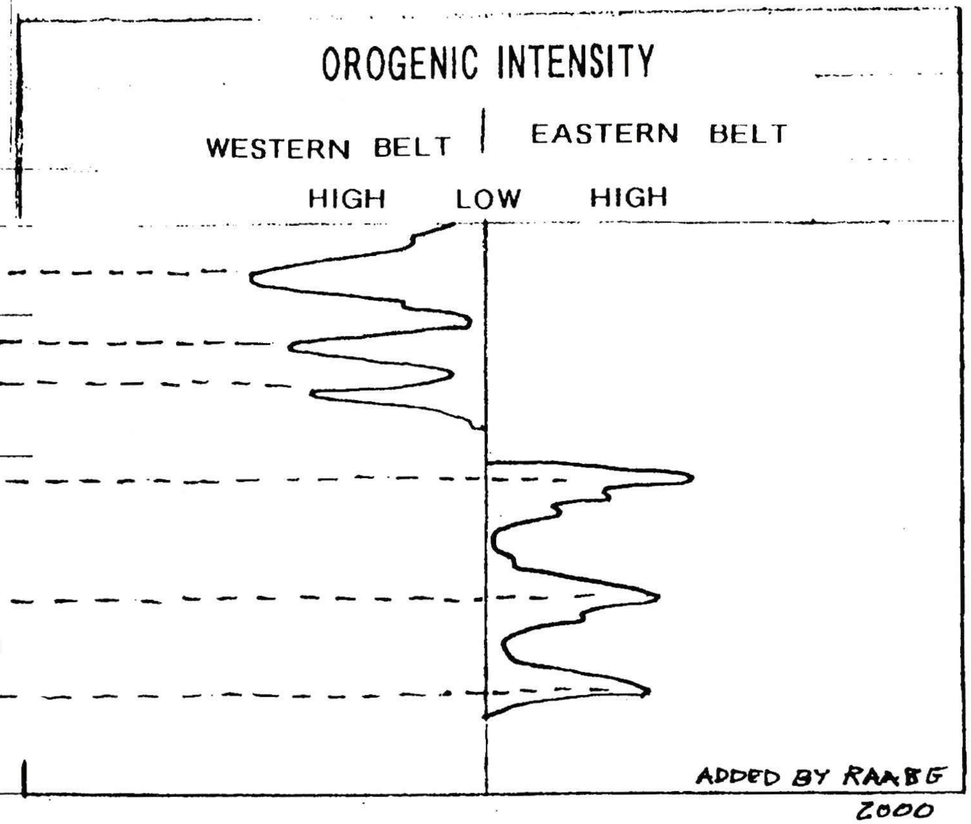
Orogenic Event



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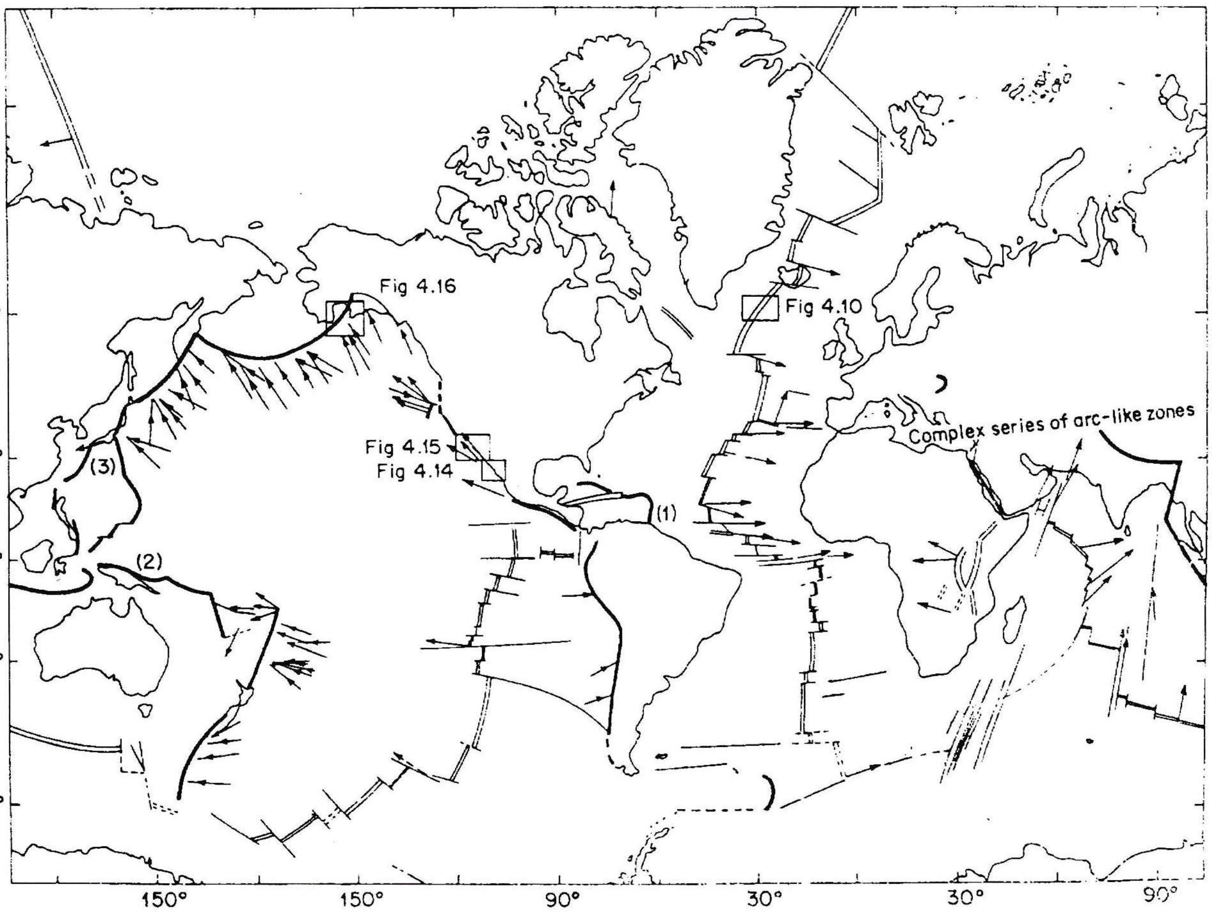
GENERALIZED PLATE TECTONIC MAP OF PRESENT CONDITIONS



Principal areas of generation of new crust (open bars) and principal areas of consumption of old crust (solid bars). Areas of crustal generation are generally tectonic highs standing 1000 to 2000 meters above the ocean basins. Areas of crustal consumption are commonly topographic lows as in the circumpacific trenches but areas of crustal consumption can also be tectonic highs, as in the Alpine-Himalaya mountain belt. The Cordilleran chain (Rockies) of western America is an area of crustal generation while in Central and South America the mountain chain is associated with crustal consumption.

After B, Isacks *et al.*, *Jour. Geophysical Research,* No. 18, 5861 (1968)

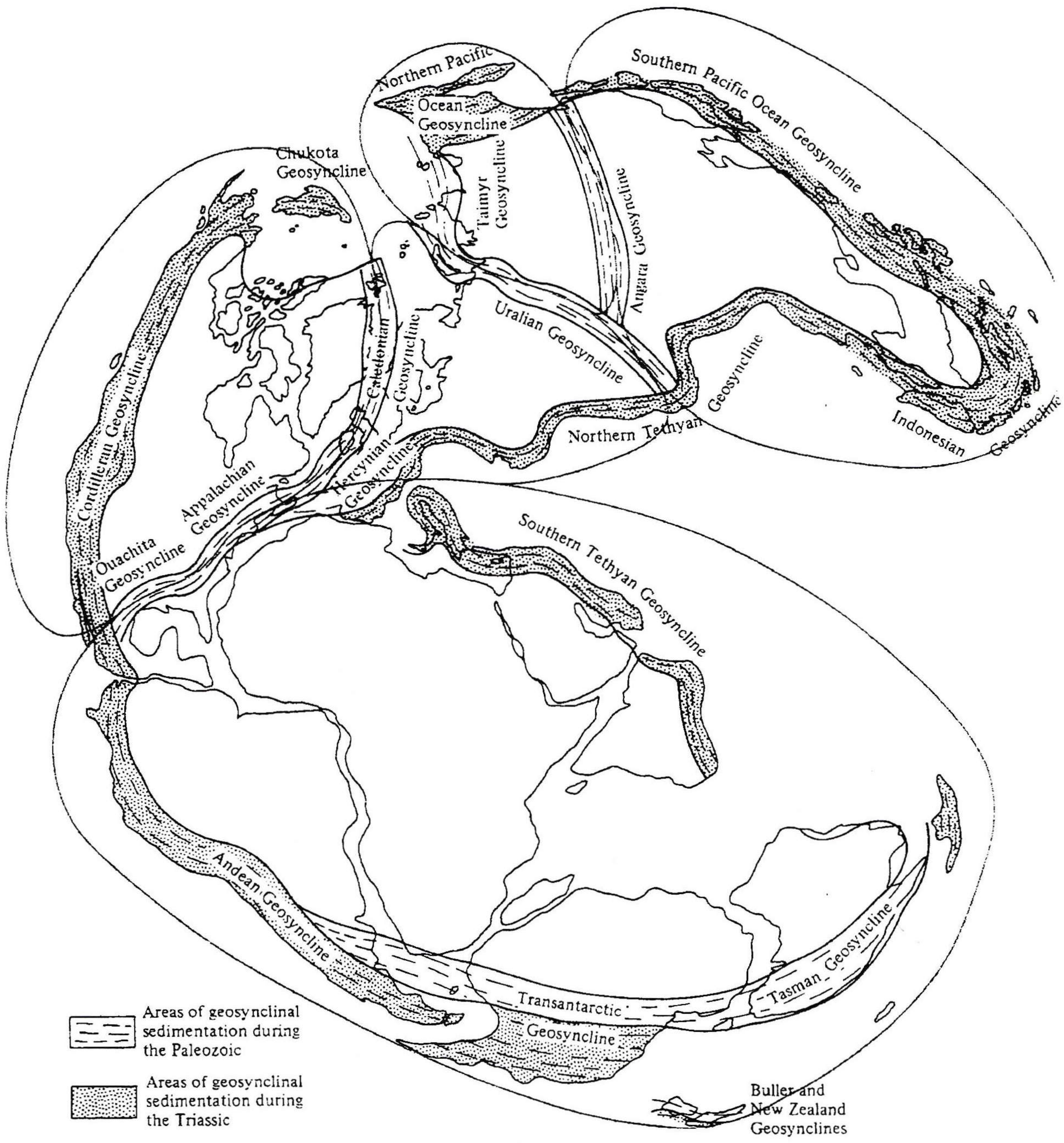
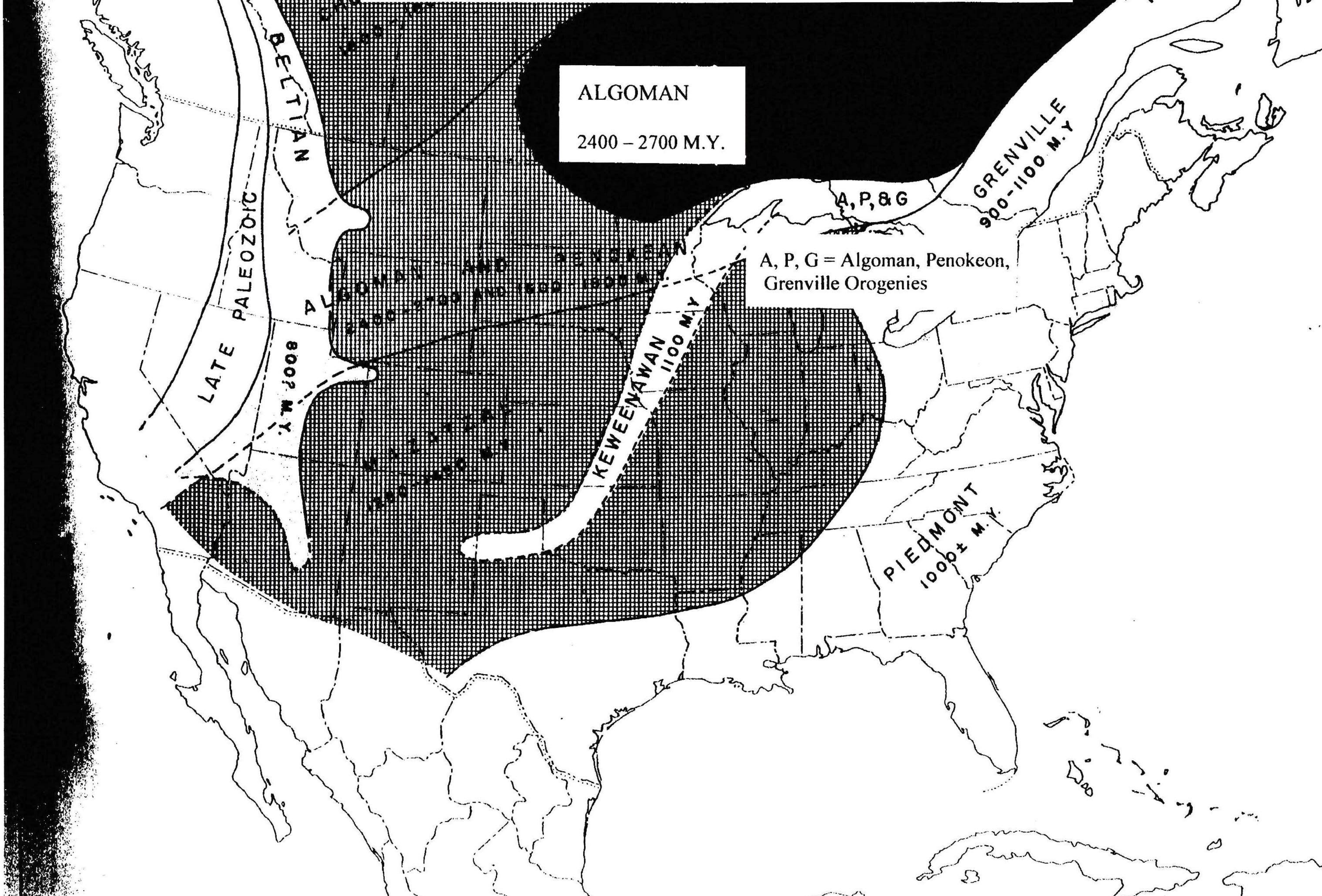


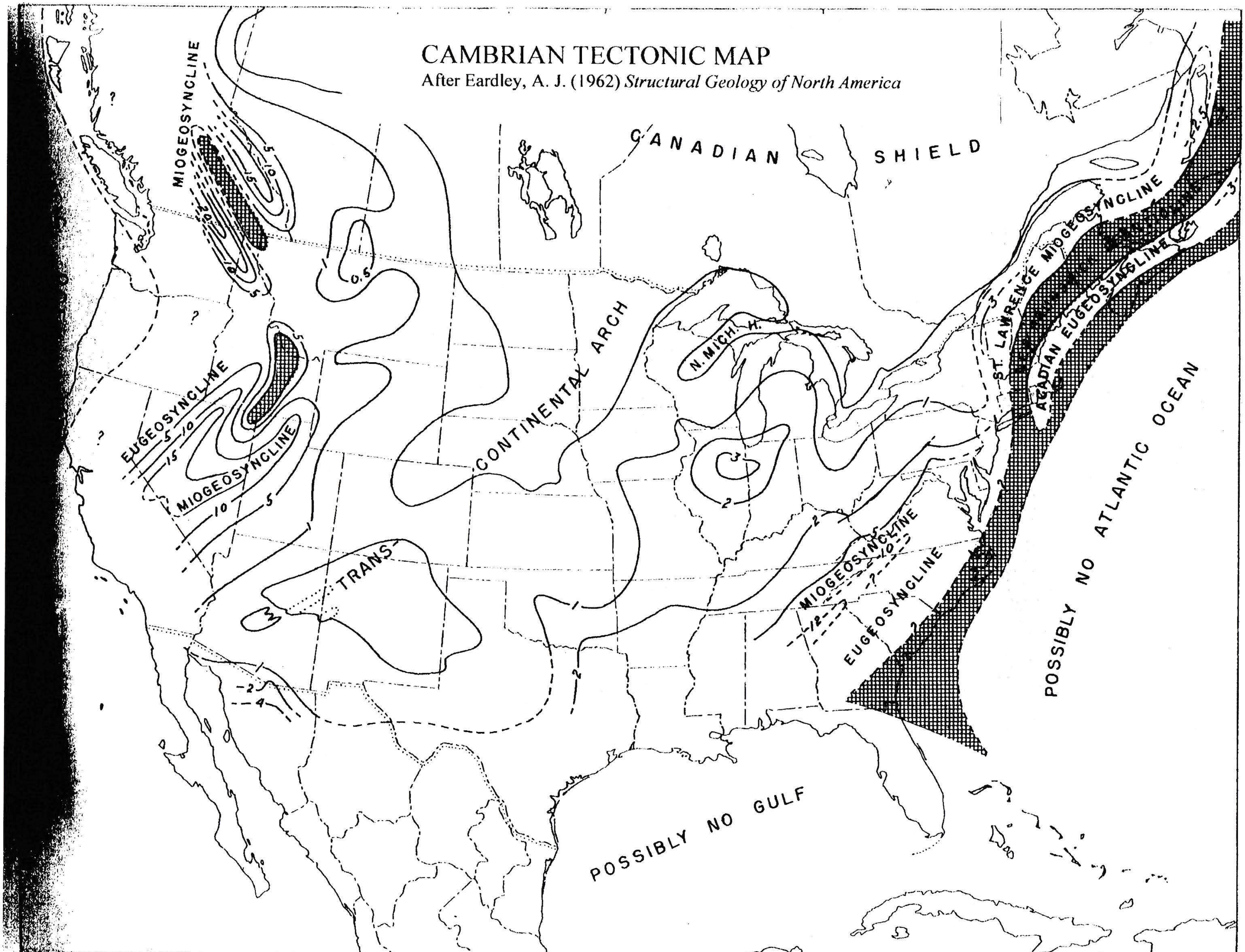
Figure 7.13 Location of Paleozoic and Triassic geosynclines plotted on a predrift reconstruction of the continents.

From: Seyfert, Carl K. and Leslie A. Sirkin (1973) *Earth History and Plate Tectonics*

PRECAMBRIAN OROGENIC BELTS

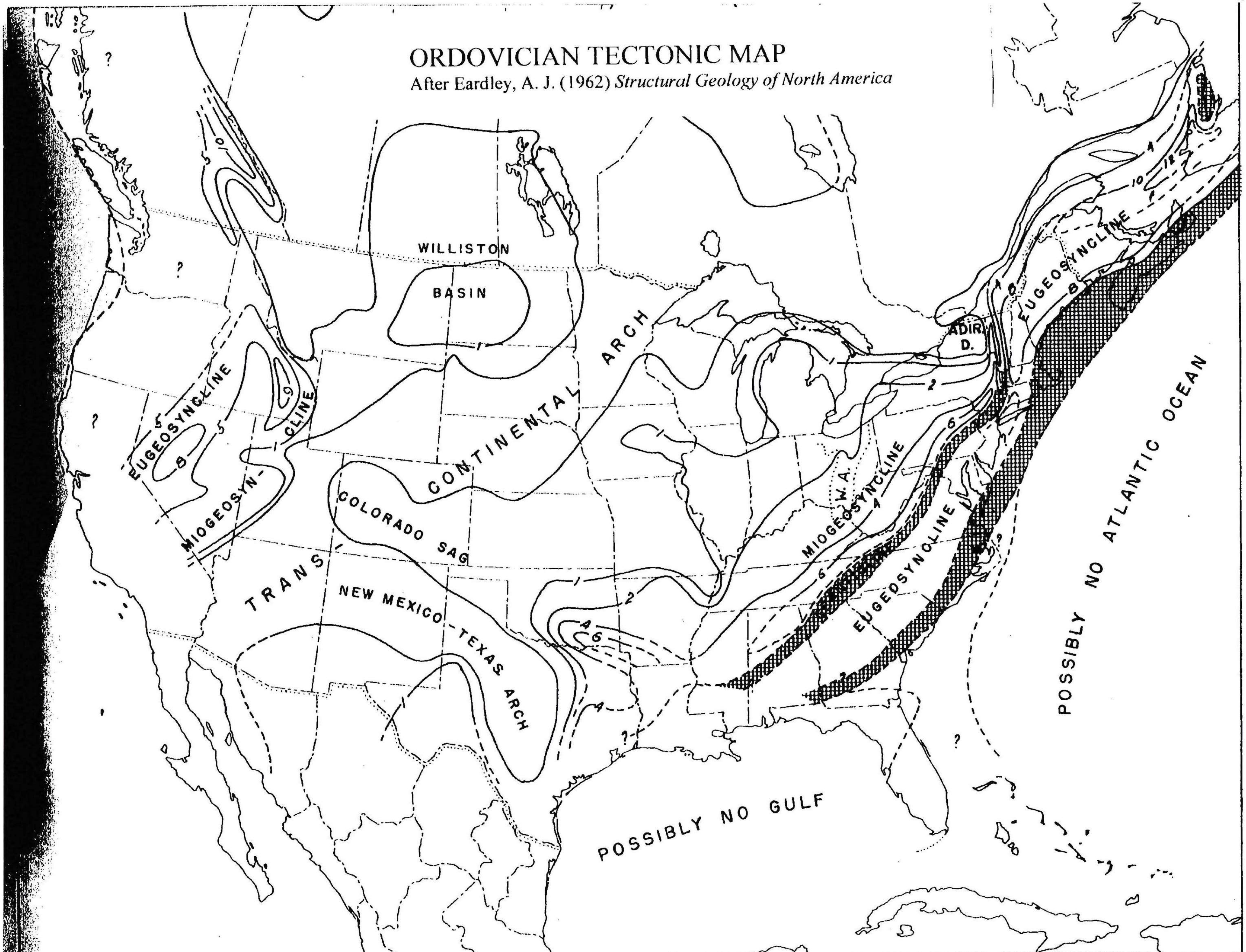
After Eardley, A. J. (1962) *Structural Geology of North America*




CAMBRIAN TECTONIC MAP
After Eardley, A. J. (1962) *Structural Geology of North America*
CANADIAN SHIELD
MIOGEOSYNCLINE
EUGEOSYNCLINE
MIOGEOSYNCLINE
CONTINENTAL ARCH
TRANS
N. MICH. H.
ST. LAWRENCE MIOGEOSYNCLINE
ACADIAN EUGEOSYNCLINE
MIOGEOSYNCLINE
EUGEOSYNCLINE
POSSIBLY NO ATLANTIC OCEAN
POSSIBLY NO GULF

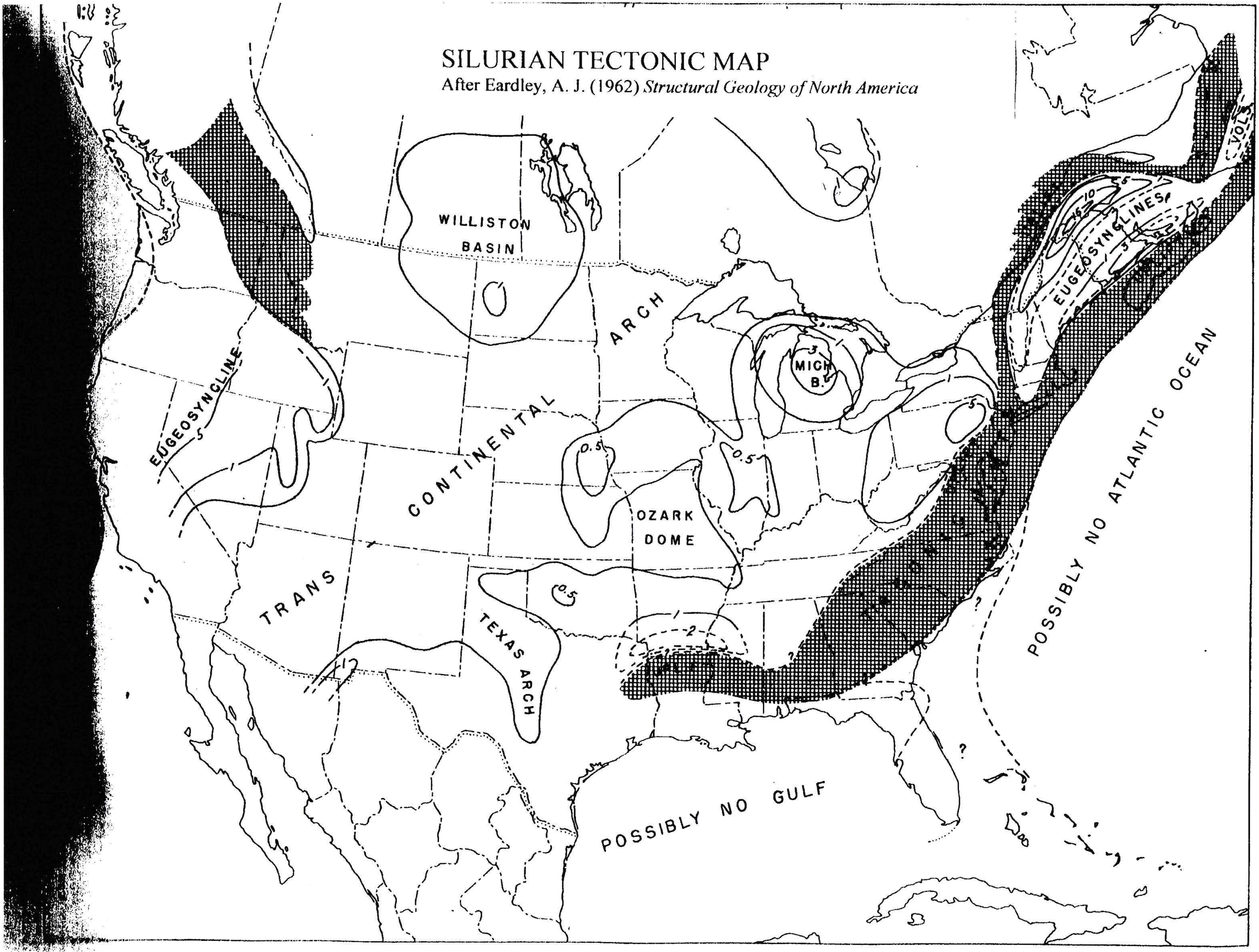
ORDOVICIAN TECTONIC MAP

After Eardley, A. J. (1962) *Structural Geology of North America*



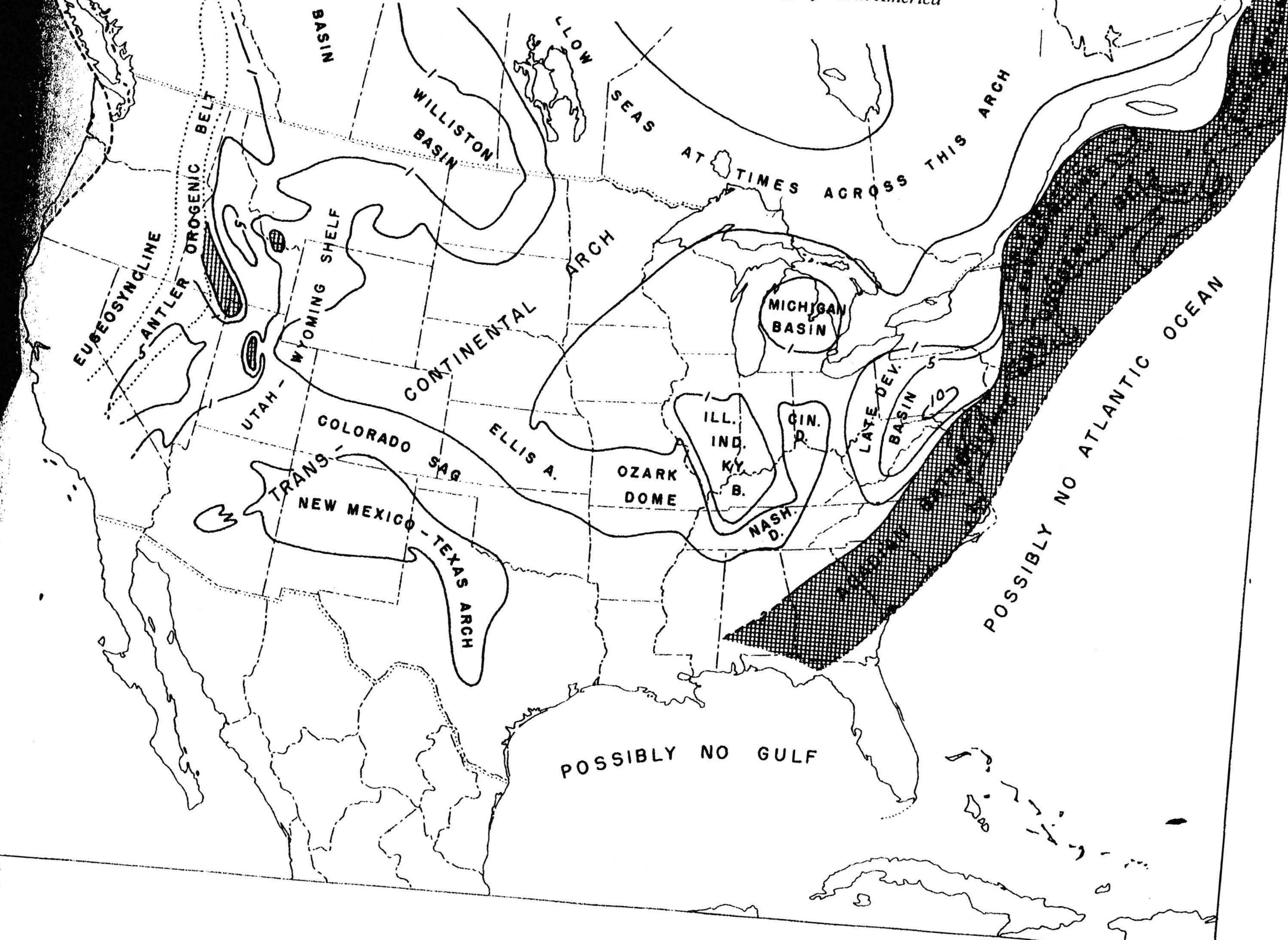
SILURIAN TECTONIC MAP

After Eardley, A. J. (1962) *Structural Geology of North America*



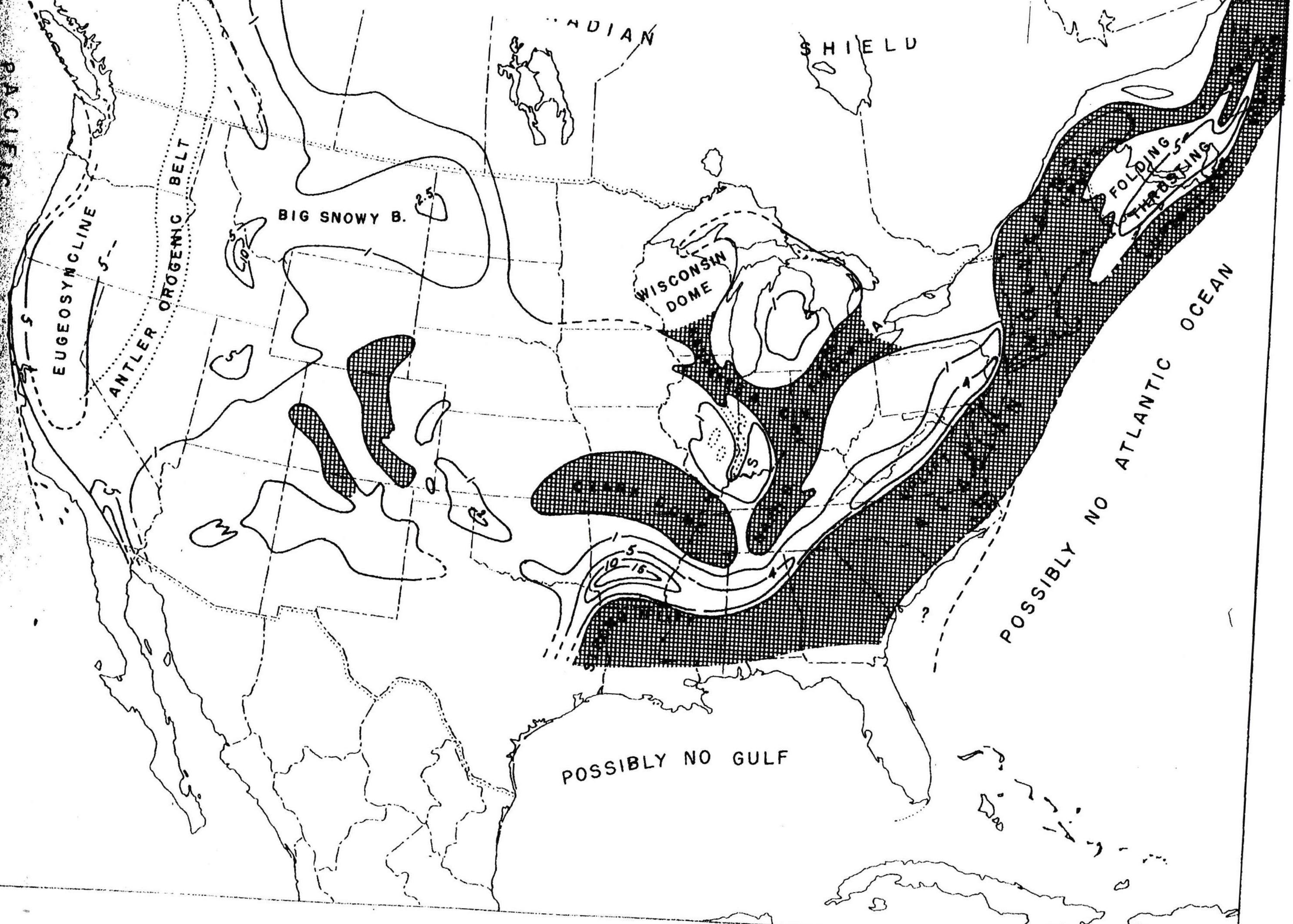
DEVONIAN TECTONIC MAP

After Eardley, A. J. (1962) *Structural Geology of North America*



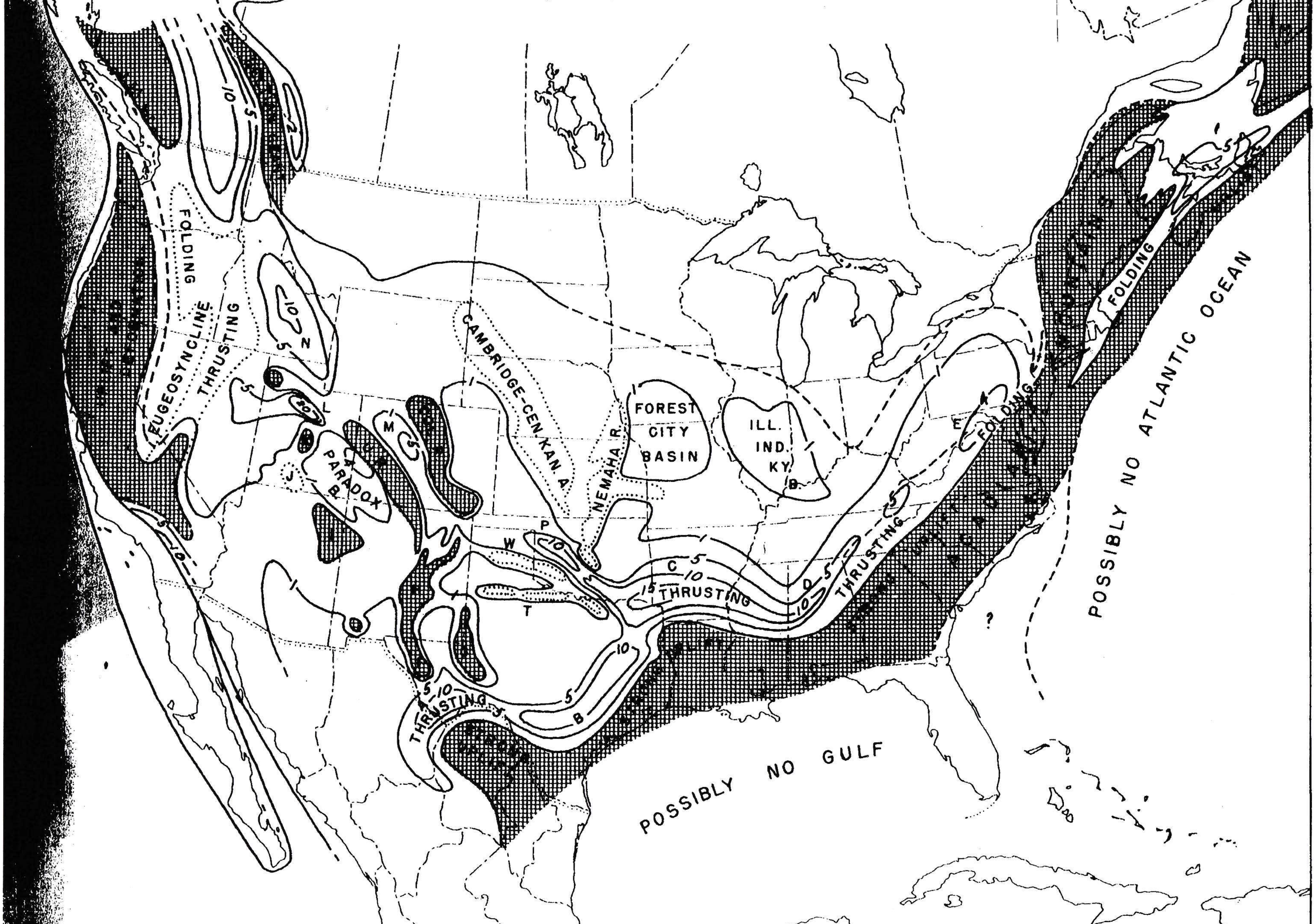
MISSISSIPPIAN TECTONIC MAP

After Eardley, A. J. (1962) *Structural Geology of North America*



PENNSYLVANIAN TECTONIC MAP

After Eardley, A. J. (1962) *Structural Geology of North America*



TRIASSIC TECTONIC MAP

After Eardley, A. J. (1962) *Structural Geology of North America*