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Commentary

Is the Gulf's Origin Heaven Sent?

Author's note: This paper on the Gulf came about as a spin-off of a study I have made on certain Canadian basins. The original paper was prepared in 1993, but was shelved. Since then there has been more evidence of large impact structures previously unrecognized. There is more acceptance that impacts had a greater influence on Earth's later history than previously thought.

However, the Gulf is not in my area of activity and I will welcome comments and criticisms from geologists more knowledgeable about the region, particularly in the sphere of plate tectonics.

I have taken much of the geophysical data from the 1961 landmark volume by Grover E. Murray, "Geology of the Atlantic and Gulf Coastal Provinces of North America." Certain illustrations have been reproduced untouched from this volume. Original authors are listed in the captions.

By MICHAEL S. STANTON

The origin of the Gulf of Mexico has been a long-standing point of controversy between geologists.

Several theories have been presented to explain the "hole" in the Bullard-type jigsaw fit of the continental masses. All involve plate tectonic reconstructions – but none have proven fully satisfactory.

I propose that the origin was not due to traditional mechanisms from below, but to a huge cosmic impact from above.

This may seem improbable to most geologists, but there are many features favoring such an event, including morphology, geophysics, metamorphic gradient, possibly orogenic tectonism, faulting and an ideal focus of deposition for the Louann Salt. The lack of pre-Late Triassic information leaves room for speculation.

Plate tectonic reconstructions fail to explain the lack of magnetic signature expected in a rift basin, nor the Tethyan space problems imposed by rotation of South America to fill the Gulf.

An impact origin would answer both of those difficulties. The "hole" in the mosaic has been there from the moment of impact.

I'm suggesting that a huge cosmic impact (asteroid or comet) struck the area of the present gulf in latest Permian time, creating an immense saucer-like crater, fracturing the crust, metamorphosing the underlying Paleozoic rocks (impact melt?) and causing an uplifted Moho due to rebound tectonics.

This impact is seen as responsible for the world's greatest extinction crisis at the close of the Permian, some 250 million years ago. It may also have contributed to Permian glaciation of southern Pangea.

It's interesting that extinction crises also occurred at the Cambro/Ordovician, Ordo/Siluiian, Devonian/Mississippian and Triassic/Jurassic boundaries – and it is tempting to suggest that these crises also were triggered by asteroid/comet impacts.

If one accepts the possibility of cosmic origin, then the following speculative scenario is proposed:

❒ The Gulf of Mexico area was hit by a huge asteroid or comet at the close of the Permian. It accounted for the great Permian extinction crisis and perhaps contributed to Permian glaciation.

❒ It created an immense crater and resulted in an uplifted Moho due to rebound tectonics.

❒ Impact metamorphosed underlying Paleozoic sediments and created down to basin faulting and basinal grabens.

❒ The hot impact basin with a silled outlet to the open ocean offered an ideal evaporating pan for deposition of the Louann Salt.

❒ Impact ruptured crustal integrity, caused an uplifted Moho by rebound tectonics and probably induced deep-seated radially-outward motions in the ductile mantle. This area of impact may have been the trigger that initiated tripartite continental separation (similar to a triple junction).

The Gulf was continental land area prior to the Pangean breakup, and the "hole" in the Bullard mosaic did not exist until impact. There is no need for plate tectonic reconstruction to fill the gap. The Gulf of Mexico was formed by impact from above, not by traditional plate tectonics from below.

The 35 million-year-old Chesapeake Bay area has now been identified as a large impact structure. How many others have gone unrecognized?

Are we overlooking the obvious because of the immense size of the Gulf of Mexico?

Look again at a map or a satellite image of the Gulf – and think "impact crater." It would solve many perplexing problems of the Gulf's origin.

Impact Craters

When I first presented the idea that the Gulf of Mexico may have formed by asteroid impact I was told that the flux was against the concept. But this is indeed a valid argument.

From lunar evidence, there are five stages in the moon's history (Moore and Ifunt, 1990). Earth was subjected to the same cosmic bombardment as the moon. The period of massive impact craters and mare basin formation occurred from 4,500 to 3,850 million years ago – a period of cosmic sweep.

The flux (size and frequency) of asteroid impact has decreased dramatically from this time, and the period from 1000 mya to the present is described as largely quiescent with minor cratering. This spans the later Proterozoic and all of the Phanerozoic.

Of course, comets are different in composition and trajectories, and I question whether the statistics of asteroid flux are applicable to comets.

Regardless, statistical flux does not preclude large random impacts that are known to have occurred in later times. There are over 3,000 asteroids in the asteroid belt identified to date, the largest of which is Ceres with a diameter of 940 km. That belt is beyond Earth's orbit, but they're many others, collectively called Apollos, that have Earth-crossing trajectories.

Hildebrand (1999) states there are more than 1,000 asteroids larger than 1 km that regularly hurtle across the Earth's path. New comets are discovered regularly that have earth-crossing paths.

A large asteroid (1997 XFIII) was originally thought to be on a possible collision course with Earth in 2028, but later calculations showed a safe separation. That asteroid is 1.6 km in diameter, and should it impact the earth, one astronomer estimated its effect would be equivalent to about 100 million times the force of the Hiroshima bomb.

Speaking of asteroids:

✓ Chesapeake Bay, of course, was the site of a large asteroid impact some 35 million years ago (Eocene). The crater is 82 kilometers across.

✓ The Popigei crater in Siberia is 100 kilometers in diameter, and impacted 35.7 mya, also in the Eocene.

✓ The K/T Yucatan crater is some 140 kilometers in diameter.

✓ Very recently (March 8, 2002) a 50-meter wide asteroid passed within 463,000 kilometers (287,000 miles) of Earth, slightly further than the moon. Had it struck, it would have demolished an area the size of Prince Edward Island according to one authority. It was not predicted, and was discovered four days later as it departed.

The moon is completely covered by craters – a "fossil" record of the type of bombardment also suffered by Earth. But the evidence on Earth has been largely removed or obscured on land by tectonics, erosion, sedimentation and other activities not operative on the moon. Subduction processes have removed any evidence of pre-Triassic impacts at sea. Only very large impacts can be expected to show present day surface evidence.

Of course, I believe the Gulf is one of those.

The Gulf of Mexico is comparable in size to some of the moon's huge maria. Mare Orientale on the far side of the moon is 900 kin (560 miles) in diameter and is surrounded by a double ring of mountains. But most these large impacts on the moon occurred in Precambrian times by Earth standards – which brings up the problem of impact flux.

For an impact huge enough to produce the Gulf in Paleozoic times, it must have been a huge random body – perhaps comparable to the Shoemaker-Levy 9 comet train that recently struck Jupiter.

Morphology

Circular morphology is one of the dominant features of impact craters, and one can hardly miss this characteristic of the Gulf of Mexico.

With the removal of the geologically younger (Cretaceous/Tertiary) sediments of the Yucatan Peninsula, the Gulf has a remarkably circular shape. Some later tectonics have affected the western side, but not sufficient to destroy the overall circular image.

The basin extends into and underlies part of the northern land area, but still retains its basic shape. Despite its great depth of some 40,000 to 50,000 feet it is still a shallow saucer-like basin relative to its great diameter.

In contrast to a bowl-like profile of simple craters, the morphology is characteristic of large complex impacts – the basic profile of large complex craters, including central uplift, impact melt rock and down to basin faults. Though vastly larger, the Gulf shows similar features.

Geophysics and Basement Faults

Geophysics shows a steep gulfward gradient in pre-coastal rocks, accompanied by extensive downfaulting. These are basement faults, not the listric faulting of later sediments. Peripheral down-to-basin faulting' is normal for impact craters.

Regional gravity contours of the Gulf closely parallel the shoreline configuration. There is a distinct "bullseye" pattern from a central basin high (+60 milligals) to a peripheral zone (-20 milligals). This suggests a central basin uplift surrounded by an annular ring-like valley – features common to large impact structures.

Interpretation of a seismic section from Texas to the Yucatan Peninsula (in collaboration with a gravity profile) shows a greatly uplifted Mohorovicic discontinuity.

Why would such a huge uplift occur in the central Gulf?

I suggest it is due to rebound tectonics following impact. What other mechanism would explain the uplifted Moho beneath the Gulf?

The profile also shows large-scale displacement of stratigraphic units along fault zones, which apparently are reactivated to the present day. It is interesting that a similar uplifted Moho occurs beneath Hudson Bay, another huge circular basin (Precambrian) that may also be of impact origin.

Grieve & Pilkington (1996) describe the features of a large complex crater like this: " ... consists of a structurally complex rim, a downfaulted annular trough and a structurally uplifted central area."

These are all characteristics compatible with the geophysics of the Gulf of Mexico.

Plate Tectonics

Plate tectonic reconstructions of the Gulf of Mexico are several and diverse. For example, the "hole" in the Bullard-type jigsaw fit has long posed a problem for Gulf geologists.

It is not my intention to review the various constructs in the literature, but to mention that they vary from rotation of the Yucatan plate (Humphris, 1978) to the impact of South America followed by rifting (Walper, 1981).

An excellent review of the proposed mechanisms is given in the 1981 paper by Walper, but all have serious problems. A recent paper suggests that the Yucatan segment was torn away from a stretched continent in the Jurassic (Pindell et al, 2000) but fails to explain the lack of magnetic signature for this rifting. It is an attractive concept, but involves complex dynamics including several poles of rotation.

An interesting series of maps (Wilson, 1981) shows the evolution of the Gulf from Mississippian to the present. In his reconstructions, the Gulf is shown initially as a relict of the Iapetus Ocean (contemporary with the Tethys), which was filled by epicontinental clastics and later by evaporites (Louann salt) in the Middle Jurassic.

Due to rifting, early Cretaceous oceanic crust underlies the Gulf as part of the later spreading history of the North Atlantic.

The maps are realistic and appealing, but like all plate tectonic interpretations of the Gulf, pre-Mesozoic schematics are largely speculative.

Most reconstructions accept that a continental collision between South and North America preceded the Gulf's later rifting history, A satisfying schematic is the Pangean reconstruction by Walper (1981), in which the South American plate impacted North America paralleling the present northern shoreline of the Gulf. It then recoiled as a rift basin progressively opening the gulf.

The impact would neatly explain the deflection of the Appalachians and the Ouachitas as due to continental collision, with crustal adjustments along major transform faults.

However, as pointed out by Kent (1981) all currently popular Pangean reconstructions involving the clockwise rotation of South America leaves an impossibly wide (3000 km) Tethyan ocean at the longitude of Iran, which is contrary to Mideast regional geology. The further 23-degree clockwise rotation required in Walper's fit

would further accentuate the space problem.

Also, a progressively widening rift valley should leave a magnetic record as in other rift tectonics. There is no such magnetic signature in the oceanic crust of the open Gulf, nor is there rift topography, (Steam et al, 1979).

The abrupt deflection of the Appalachians and the presence of east-west trending Ouachitas seems to favor continental collision – but need this be?

An impact of this size would also create huge peripheral damage. Examination of large lunar impact craters show a ring (or rings) of impressive mountain ranges surrounding the crater. The Ouachitas fold belt is thrust northwards, and apparently overrides the eastern part of the earlier (Pennsylvanian) Arbuckles. This is well shown in a schematic (Dunbar, 1959).

Though evidence is conflicting, some wells records have shown "flat unmetamorphosed Carnbro-Ordovician rocks of the Arbuckle facies are known beneath folded and metamorphosed Carboniferous strata" (Murray). One would expect that continental collision would have involved the entire geologic section.

The tectonics of the Ouachita region also have been controversial for Gulf geologists. I suggest that similar peripheral tectonics could result either from plate tectonic collision or from cosmic impact.

However, if impact generated, there should be "mirror image" folding on the Mexican side contemporaneous with that on the northern side of the Gulf – a circular, wrap-around fold belt.

Is there such a feature?

It is clear that explanations for the early evolution of the Gulf are as diverse as they are imaginative. But none are fully satisfying. They all attempt to explain that embarrassing gap in the otherwise neat Bullard fit by the use of plate tectonic.

If we are willing to accept the possibility that a huge cosmic impact was the causal event, then the problems would disappear. The "hole" in the neat Bullard-style fit would have nothing to do with terrestrial plate tectonics. It was imposed from above and has been there since the time of impact.

Louann Salt

As with so many Gulf problems, the origin of the Louann Salt is also controversial.

Walper (1981) states:

"No universally accepted model accounts for the deposition and present distribution of the salt in the Gulf of Mexico. Just as the fit of the continents to form Pangea is a perplexing problem the problem of the salt is unsolved and the two problems appear to be interrelated."

A very cogent statement!

The Louann is one of the world's largest salt deposits. Its thickness is estimated at about 5,000 feet, but may be as thick as 3,000 metres in grabens (Raup, 1970, as reported in Walper 1981). In addition to questions on its origin, its age has been controversial – it was initially thought to be Permian, later work suggests it is Jurassic, and some workers are not convinced.

Studies have indicated it overlies Triassic Eagle Mills deposits. But Murray (p. 285) states:

"...certain paleontologists admit that in their opinion some spores from the lower part of the Louann Salt might be as old as Permian." If so, what better environment for salt deposition than a huge, deep, hot impact crater combining extreme evaporation with a silleds access to the open ocean."

Basement faulting induced by impact could create the condition for deeper local salt basins.

Regardless of its age, the geologic reason for the deposition of such a mass of salt is still debated – as described in Walper's statement above. The impact theory offers an explanation.

'Wrap-Around' Later Stratigraphic Trends

Several stratigraphic units show a distinct tendency to follow the circumference of the Gulf. This is well illustrated (in Walper) for the Upper Jurassic Upper Smackover Formation and the reef trend in the Lower Cretaceous sequence.

While this wrap-around stratigraphic trend does not in itself indicate growth around a crater, rim it is the type of trend that would be expected.

Age of the Gulf of Mexico

As stated, there are several plate tectonic reconstructions of the Gulf, but the divergence of opinion is indicative of the difficulty of assigning a satisfactory explanation for the existence of this huge "hole" in the Bullardtype jigsaw fit. A good part of the problem is the definitive statement by Salvador (1987):

"Stratigraphic reconstruction starts with the Late Triassic because little is known about the pre-Late Triassic."

In other words, the origin of the Gulf – whether by plate tectonic mechanisms as theorized, or by cosmic impact as hereby speculated – began sometime before Late Triassic.

I suggest that the Gulf had its origin at the close of Permian time.

Permian Extinction Crisis

It is commonly accepted that the Cretaceous/Tertiary extinction crisis was the result of impact by the Chicxulub asteroid on the Yucatan Peninsula. While the K/T extinction was dramatic, there was an even greater extinction crisis at the close of the Permian. The P/Tr extinction was far more catastrophic than that of the K/T, and is "estimated to have extirpated from 75 to 90 percent of all pre-existing species." (Stanley, 1987).

If the crisis at the end of the Mesozoic was caused by an asteroid impact, it is logical to assume that the even greater crisis at the end of the Paleozoic was also caused by cosmic impact.

Where?

I suggest the Gulf of Mexico – but wouldn't it be strangely coincidental that both the K/T and P/Tr impacts occurred in the Gulf area? Certainly!

Would it not be impossible? No! There are many craters on the moon with overlapping rims.

Other Extinction Crises

It is proposed that the great Permian extinction was due to a huge cosmic impact at the Permian/Triassic time boundary. It is of interest that several other extinction crises occurred throughout Phanerozoic time, and that these also coincided closely with major period breaks.

Extinction crises marked the Cambrian/Ordovician, Ordovician/Silurian, Devonian/Mississippian, Permian/Triassic, Triassic/Jurassic, Jurassic/Cretaceous and Cretaceous/Paleocene boundaries.

It is tempting to suggest that these extinction crises also resulted from cosmic impacts that influenced major stratigraphic breaks in the geologic column.

Crustal Breakup

Acceptance of an impact origin for the Gulf raises other interesting possibilities.

For example, a huge impact would have seriously damaged the integrity of the crust, and it would also have created deep-seated rebound tectonics (uplifted Moho) and probable pressure-induced motion in the ductile mantle following the collapse phase.

Such effects are similar to those of a triple junction, though of different origin.
Impact-induced pressure could have induce a sluggish motion in the ductile mantle radially outwards from the area of impact. Once the integrity of the crust has been ruptured, such deep-seated uplift and subsequent mantle motion might have been the initiating trigger for later continental separation.

A glance at a map of the Pangean continental assembly prior to breakup shows the Gulf to be at the critical central location in the tripartite separation of the continents of North and South America and Africa. An impact at the Permian/Triassic boundary would place the Gulf basin in the right place at the right time.

Speculation, yes. But something initiated separation from this region!

Wilson stated that "It is possible that readjustments of the earth's thermal regimes, caused by continental collision, may have initiated the earliest stages of uplift, continental attenuation and block faulting during late Permian times."

I suggest that a huge cosmic impact would produce the same effects.

Ground Proof?

Though I believe there is compelling evidence that the Gulf originated from a huge asteroid/comet impact at the close of Permian times, there is the problem of ground proof.

Unfortunately most potential evidence is deeply buried beneath coastal plain sediments, so if any ground proof exists it would likely be in peripheral areas such as in or near the Ouachitas, or from drilling records.

Documented impacts have certain parameters used as evidence, including shocked quartz, planar structures, diaplectic glass, coesite, shatter cones, presence of melt rock, shock metamorphism and a breccia lens underlying and/or flanking the crater. Chemical indicators include the presence of sideritic elements or an iridium layer. The latter might be absent in the case of a comet impact.

However as stated previously, nothing is known of pre-Late Triassic stratigraphy in the Gulf coastal province (though some believe basal Louann salt may be as old as Permian). Basement rocks in the Gulf are believed to be metamorphosed Paleozoics. It thus appears that any stratigraphic evidence of the Permian/Triassic boundary has been metamorphosed or obliterated (vaporized?), which makes ground proof of this time interval unlikely.

This prompts a question: Could the underlying metamorphosed Paleozoics be "melt rock" resulting from "shock metamorphism" of cosmic impact?

Also, what tectonic mechanism other than impact rebound could account for the greatly uplifted Moho beneath the central gulf?

To my knowledge none of the ground proof criteria have been reported in the Gulf area – but if strata of the critical Permian/Triassic boundary are absent (or metamorphosed), any indicators has been obliterated. Evidence, if it exists, would likely be far distant from the Gulf proper.

The Mexican side may offer better prospects?

Scenario

If one is willing to accept the possibility that cosmic impact was responsible for the crater-like Gulf, then the following scenario is proposed:

❒ The Gulf of Mexico area was hit by a huge asteroid or comet at the close of the Permian. It accounted for the great Permian extinction crisis and perhaps contributed to Permian glaciation.

❒ It created an immense crater and resulted in an uplifted Moho due to rebound tectonics.

❒ Impact metamorphosed underlying Paleozoic sediments and created down to basin faulting and basinal grabens. The hot impact basin with a silled outlet to the open ocean offered an ideal evaporating pan for deposition of the Louann Salt.

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❒ The Gulf was continental land area prior to the Pangean breakup, and the "bole" in the Bullard mosaic did not exist until impact. There is no need for plate tectonic reconstruction to fill the gap. The Gulf of Mexico was formed by impact from above, not by traditional plate tectonics from below.

Are we overlooking the obvious because of the sheer size of the Gulf? Next time you look at a map or a satellite image of the Gulf of Mexico, think "impact crater." It works for me.

(Editor's note: Stanton, an AAPG member, is a retired geologist residing in Calgary, Canada.)