Quartzarenites violate the uniformitarian principle

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Many unusual sedimentary rocks occur on Earth. One of these is quartzarenite, a type of cemented sandstone. The sand that makes up quartzarenite does not appear to be forming today, while an enormous amount of quartzarenite is found in the sedimentary rock record, especially in the Precambrian and Paleozoic. Quartzarenites convey important information for creation scientists working on a Flood model.

The four main types of sandstone

Cemented sandstone makes up 20 to 25% of all sedimentary rocks.[1] Sandstone has classically been divided into four main types that would categorize practically all sandstones.[2] They are: (1) quartzarenite, (2) lithic arenite, (3) arkose, and (4) graywacke.[3] A quartzarenite is a 'mature' or 'supermature' cemented sandstone in which the individual grains are 90–95% quartz and rounded to well rounded.[4,5] If a sandstone has a fair percentage of rock fragments, usually greater than 50%, with a lesser percentage of feldspar, it is termed a 'lithic arenite'. Sands with 25% or more feldspar with a smaller percentage of rock fragments are identified as an arkose. Graywacke is defined by a fine-grained matrix greater than 15% between the sand particles. This classification does not include the cements (e.g., silica and sometimes carbonate and other cements) that bind the individual sand grains into sandstone.

The classification of sandstones has always been difficult, probably because each sandstone has a variable amount of the three main framework grains: quartz, feldspar, and lithics (figure 1). Sedimentologist Eduardo Garzanti has devised a new classification for sandstones incorporating some of the older terminology and subdividing it.[6] One of the reasons for the new classification is that he believes the older classification systems use

> "… cumbersome petrographic descriptions based on obsolete classification schemes or awkward terms such as arkose or greywacke, the use of which has been contested since their early introduction two centuries ago."[7]

Garzanti's classification is intuitive, but would require extensive analysis of the sixteen individual types of sandstone to determine its proper abundance or origin. Despite the terms 'arkose' and 'greywacke' being vague, this paper and a companion paper will examine the four classical descriptions of sandstone to question how well they can be accounted for by uniformitarianism, simply stated as 'the present is the key to the past'.

What is a quartzarenite?

Quartzarenites are common sandstones and are believed to make up about 33% of all sandstones according to Boggs,[8] a percentage he obtained from Pettijohn. Then quartzarenites make up about 7–8% of all sedimentary rocks, a not insignificant volume.

However, the definition of quartzarenite is not straightforward.[9] The precise definition likely has caused confusion about whether the sand that makes up quartzarenite is forming today or not, and how prevalent it is in the rock record. A few researchers think that the amount of cemented quartz grains needs to be greater than 90% while most believe it needs to be greater than 95%.[10,11] This is called mineralogical or compositional 'maturity'. Textural maturity consists of the quartz grains being rounded to well-rounded. Some researchers assume that mineralogical maturity is all that is needed to call the cemented sand a quartzarenite.[12] However, most researchers consider that a quartzarenite needs both mineralogical and textural maturity,[13] which is the definition used in this paper.

Quartzarenite is sometimes metamorphosed to metaquartzite or simply quartzite (figure 2). There is another type of quartzite, not discussed in this paper, that is not metamorphosed and is called 'orthoquartzite', a hard cemented sandstone. Metaquartzite is commonly associated with continental cratons and has few interbeds of fine-grained sedimentary rocks.[14] Quartzarenites and metaquartzite are predominantly cemented by silica.[15]

Quartzarenite must first start as individual quartz sand grains in which most of the other lithologies disappear. It is likely that the quartz comes from the weathering or disintegration of igneous and metamorphic rocks that contain much quartz, such as granite. However, it is difficult to

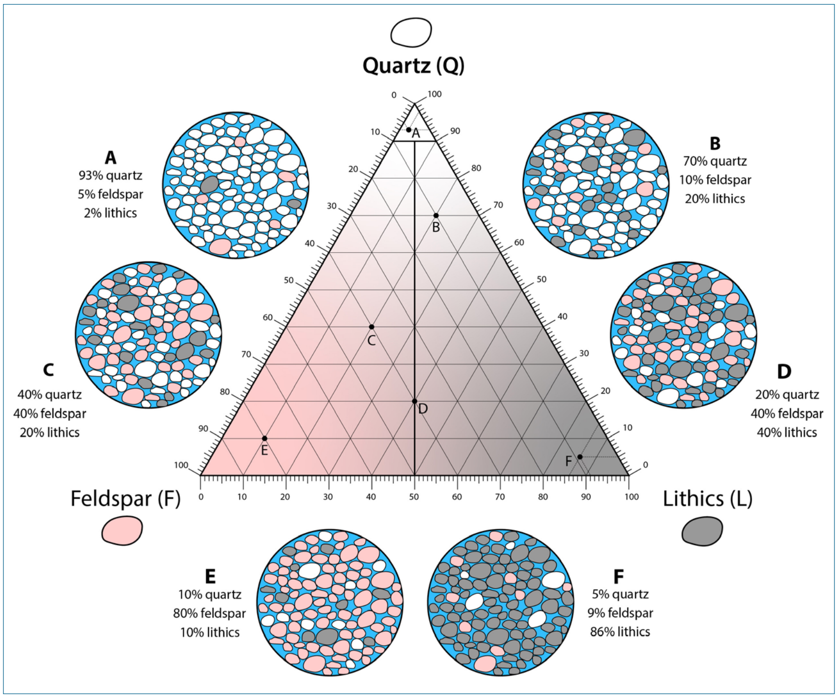

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Figure 1. Classic sandstone ternary diagram showing the relative abundance of quartz, feldspar, and lithics (rock particles) in a sandstone with six thin sections colour-coded, showing what those abundances would look like.

Figure 2. Well-rounded quartzite boulder transported from the southwest over 100 km and found on top of the Gravelly Mountains, southwest Montana, USA. Note the vitreous texture in the lower left from the metamorphism. The boulder has numerous percussion marks, not forming today on quartzite and indicating torrential water flow.

envisage a geological process that can account for it: "How can we explain the complete disposal [weathering] of at least 75% of any ultimate parent igneous or metamorphic rock to yield a residue that is at least 95% quartz sand?"[16] The sand that makes up quartzarenites is considered 'first-cycle' if it formed *directly* by chemical and/or mechanical weathering processes from mainly igneous or metamorphic rocks and then became well-rounded. But if the sand grains originate from a *pre-existing* quartzarenite, then the sand is considered a 'multi-cycle' quartz sand. When it is cemented, it would be a multi-cycle quartzarenite.

From that sedimentary base, somehow the quartz grains then become well rounded by the action of water. Then they are deeply buried and subject to migrating silica-rich fluids that cement the sand grains into a quartzarenite. Then the quartzarenite must be uplifted with overburden eroded, when the quartzarenite is found at the surface.

Quartzarenites are sometimes enormous

The sedimentary rock record includes enormous volumes of quartzarenite, such as the 1,000 m thick Precambrian Athabaska Formation of northern Saskatchewan, Canada, which covers 104,000 km^2.[17] The Thelon Formation in the northwest Territories of Canada is of similar extent.[17] The Cambrian/Ordovician Jura Quartzite, a metamorphosed quartzarenite, is an impressive 5,300 m thick![18]

Quartzarenite can sometimes be deposited as a thin widespread sheet of sandstone, especially in the early Paleozoic, such as the Ordovician St. Peter Sandstone, which thinly outcrops over much of the middle USA over an area of 582,750 km^2.[19] A vast sheet of quartzarenite with a volume of 15 million km^3 was laid down in northern Africa from the Atlantic coast to the Persian Gulf in Cambrian/Ordovician times by paleocurrents flowing toward the north.[20]

The sensational Roraima quartzarenite

The Paleoproterozoic Roraima Formation (or Supergroup), which outcrops mostly in Venezuela (figure 3) is mostly a quartzarenite that is greater than 2,500 m thick. It once covered a huge area of about 250,000 km^2, but has been 90% eroded into erosional remnants in the form of high mesas and plateaus, called 'tepuis'.[21,22] The sandstone is only slightly metamorphosed and forms local quartzite. The area is mysteriously riddled with large caves and deep sink holes on top of some tepuis. The world's largest waterfall, Angel Falls, is in this region. However, if far outliers are included, the sand would have been deposited over an area of 2.4 × 10^6 km^2, an area four times that of France.[21] There are over 100 of these mesas and plateaus. The tepuis can be up to 1,000 m above the forest floor (figure 4)![23] The top of the tepuis is considered an eroded planation surface with the amount of erosion believed to be about 3,000 m![23] The deposition and erosion of the Roraima Formation indicates powerful catastrophic action during the Paleoproterozoic.

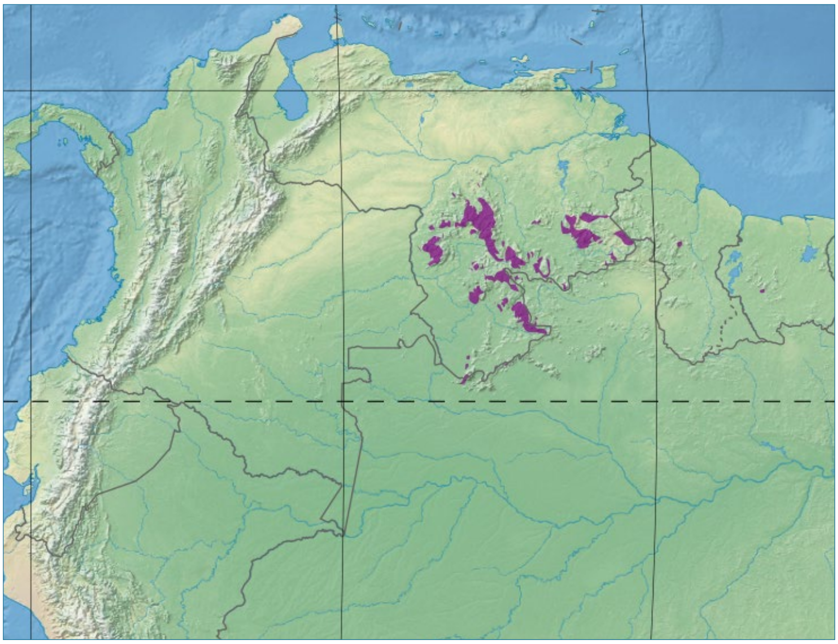

Image: Every-leaf-that-trembles, Wikimedia / CC BY SA 4.0

Figure 3. Location of tepuis mostly in southeastern Venezuela

Image: Paolo Costa Baldi, Wikimedia / CC BY SA 3.0

Figure 4. Kukenan Tepuy in Gran Sabana National Park, Venezuela, that is 2,700–2,800 m asl

The temporal distribution of quartzarenites

What is the temporal occurrence of quartzarenites, assuming the geological column, and what is the significance? Much more quartzarenite occurs in the Precambrian, decreasing upward in the Phanerozoic. Dott states:

> "In reality, there are far greater volumes of pure quartz arenites in the Precambrian than in the Phanerozoic record. They occur on most continents, and many are hardly sheetlike, being hundreds to thousands of meters thick."[24]

Quartzarenite is even found in the early and late Archean.[18]

Moreover, Precambrian and lower Paleozoic quartzarenites are commonly medium to coarse grained with very few shale interbeds compared to other sandstones. For instance, quartzarenites are globally distributed on top of the Precambrian/Cambrian Great Unconformity, as Lorentzen *et al.* state: "Lower Cambrian quartz arenite deposits have a world-wide occurrence".[25]

Are first-cycle well-rounded, nearly pure quartz sands forming today?

Before we even consider the formation of a cemented quartzarenite, an important question to consider is whether first-cycle well-rounded, nearly pure quartz sand is being produced today anywhere on the earth? This is important in considering whether the sand that forms quartzarenite violates the uniformitarian principle or not. Conventional scientists believe that there are two locations on Earth where high quartz sand is forming today. These are areas of intense chemical weathering in a hot, humid climate with leaching by acidic rainwater or by organic acids in the soil. A stable, generally flat terrane ensures a long residence time for weathering to reach completion. Such an environment would cause the more stable grains, mainly quartz and ZTR (zircon, tourmaline, rutile] minerals to become more concentrated. Such an environment can be found in the rain belts of northern South America and the Congo drainage basin of Central Africa.

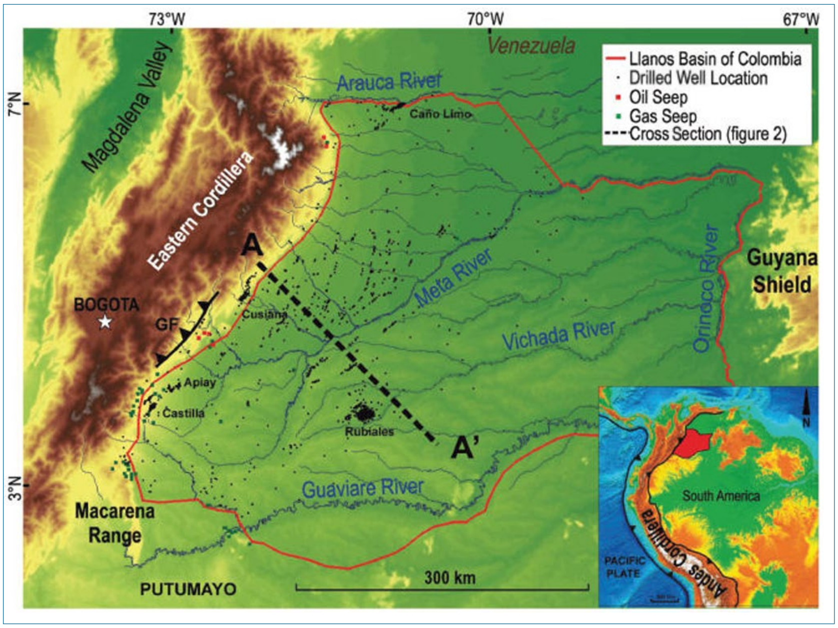

Figure 5. The bottom right inset presents the eastern forelands of the northern Andes, west of the Guyana Shield in Colombia (from Gonzalez-Penagos *et al*., ref. 30). The Llanos Basin is outlined in red near the top of the figure. The main map shows the topography colour coded by altitude with reddish-brown indicating high altitude and green, low altitude. Also shown are the fluvial system, the oil and gas seep occurrence, and the drilled well locations.

South America

Johnsson *et al*. claim first-cycle quartz sand can form by intense chemical weathering over extended periods of time. They believe it has been forming on top of granite in the eastern Llanos Basin, east of the Andes in Columbia and southern Venezuela and on low-relief surfaces of the western Guyana Shield (figures 5 and 6).[26,27] The climate is warm and humid, and drainage is by the Orinoco River of northern South America (figure 7). The intense chemical weathering leaves behind the quartz from the weathered granite, and, over an extended period, time supposedly allows multiple passes through the 'fluvial system' to reach textural maturity: "But what of the textural criteria? It seems reasonable that multiple passes through a fluvial system should result in increased roundness."[28] However, this is contrary to the experimental work of Keunen, who showed that water does not round sand grains.[29] Garzanti also disagrees with the conclusions of Johnsson *et al.* and considers it a myth that physical processes, such as fluvial, littoral, and even wind transport, can result in a mature or supermature sandstone.[4]

There is another problem with the idea that first-order quartz sand is forming in the tropical jungles of South America. East of the Orinoco River and part of the Guyana Shield is the Roraima Formation, which is predominantly quartzarenite. The formation has been highly eroded (see above), so that much of the claimed quartzarenite would be erosional detritus. However, Johnsson *et al.* disagree that their high quartz sand came from sand eroded from the Roraima Formation. Their evidence is that the lowland, granitic Guyana Shield sand is more rounded than the quartz eroded from the Roraima Formation. However, this is because the quartz eroded from the Roraima Formation still has rough cement overgrowths that cap the well-rounded grains of the Roraima quartzarenite. Johnsson *et al*. do admit more study is needed on textural maturity: "The discrimination between first- and multi-cycle quartz arenites is exceedingly difficult."[28]

Potter examined sand in many rivers of South America besides the Orinoco drainage basin.[31] He discovered that quartz sand occurs in all rivers draining cratons, especially the Guyana and Brazilian Shields, which have several widespread erosional surfaces. This represents 62% of South America. Potter does postulate that Johnsson and colleagues' Orinoco River sands have been contaminated by the erosion of quartzarenite from the shields, i.e., the Roraima Formation. Although the river sands have compositional maturity, Potter identified the sand on low-relief shield areas as *subangular*; it is not texturally mature. Dott also recognizes that the sands of the Orinoco drainage basin are texturally immature.[24] In summary, the quartz sand analyzed by Johnsson and colleagues is mineralogically mature, but it is not texturally mature, unlike practically all lithified quartzarenites in the rock record.

The Congo Basin

Another hot, humid, and stable environment is the Congo Basin of Central Africa (figure 8), where first-cycle quartz sand could be forming. Indeed, the Congo River is delivering high-quartz sand that is mostly rounded to well-rounded to its mouth.[32,33] However, Garzanti and colleagues show that the mature quartz sand is probably not from intense chemical weathering, although this is occurring in Central Africa. This is because numerous ancient ultra-pure quartzarenite sandstones also occur in the Congo River Basin. Thus, it is difficult to prove whether the quartz sand from the Congo Basin is first- or multi-cycled.[32,34] In fact, Garzanti *et al.* believe the quartz sand of the Congo Basin is multi-cycled: "Quartz abundance thus chiefly reflects the abundance of quartzose sandstone in the catchment and recycling, rather than weathering intensity."[35] They state: "Pure quartzose sand occurs only in catchments where cover strata including thick upper Proterozoic quartzarenite is exposed."[9]

Quartzarenites violate the uniformitarianism principle

Despite the claims of some researchers, such as Johnsson and colleagues, first-cycle well-rounded clean quartz sands apparently are not forming today.

> "A never solved problem in sedimentary petrology is the origin of sandstone consisting exclusively of quartz and most durable heavy minerals."[36]

Because of the difficulty today of forming such sand, the researchers in the Congo River drainage claim that most, if not all, ancient quartzarenite sandstones must also be multicycled. But this begs the question of how do the first-cycle mineralogically and texturally mature quartz sands originate in the first place, especially considering the enormous sizes of the formations that contain quartzarenite (see above)? Chemical weathering in a warm, wet environment with little relief is not enough.

> "Moreover, the abundance of pure quartzarenite in the rock record can hardly be explained by chemical weathering or physical recycling alone."[36]
>
> "… first-cycle sand consisting of quartz and ZTR minerals exclusively cannot be generated by chemical weathering alone in the atmospheric and climatic conditions of the modern Earth".[37]

As a result, sedimentologists have been debating the origin of quartzarenites for well over 100 years. The very existence of such sandstones presents a challenge to the uniformitarian principle, the assumption which undergirds their research.

> "Another seeming 'non-uniformitarian' kind of sandstone is the extremely thick quartz arenite that seems to be widespread in the upper Precambrian. Quartzites [mainly orthoquartzite or hard cemented sandstone] such as the Lorrain of Ontario, the Baraboo of Wisconsin, the Athabaska of Saskatchewan, and the Uinta of Utah are all very pure and well over 1000 m thick whereas Phanerozoic quartz arenites tend to be very thin, rarely over a few tens of meters thick."[38]

It is interesting to note the difference between Precambrian and Phanerozoic quartzarenites, but, regardless, the formation of the original well-rounded, nearly pure quartz sand, as well as quartzarenites, violates the uniformitarian or actualistic principle, as also reinforced by Dott:

> "A century-long debate over the origin of these remarkably pure sandstones has remained unresolved, largely because they seem nonactualistic."[39]

In a more recent article, Konstantinou *et al.* declare, "Despite numerous studies, the century-long debate on how these arenites formed is still unresolved, primarily because

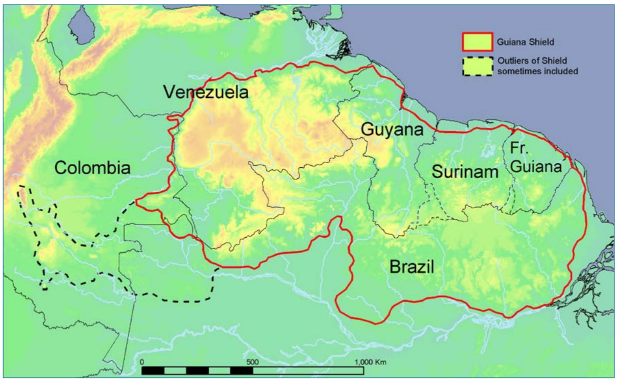

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Figure 6. The Guyana Shield of northern South America colour-coded by altitude, with brown colours showing high altitude, and green colours, low altitude

Image: Mileniuscura, Wikimedia / CC BY SA 4.0

Figure 7. Orinoco drainage basin

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Figure 8. The Congo River drainage basin

of the compositional and textural purity of the deposits."[40] Pastore *et al*. support this conclusion:

> "The debate on the existence of first-cycle quartzarenites went on for long [sic]… , until the modern-sand lesson indicated unambiguously that sand consisting virtually entirely of quartz and ZTR minerals cannot be the result of mechanical or weathering processes even in the most aggressive climatic conditions met in modern Earth, but that the final cleansing of less stable minerals requires extensive intrastratal dissolution, i.e., inheritance from previous sedimentary cycles of weathering and diagenesis … . Pure quartzose composition thus implies that sand originated from homogenization of detritus chiefly produced by physical disaggregation of quartz-rich parent sandstones, possibly derived in turn from older granparent [sic] sandstones, along a line of ancestry rooted in the deep past."[41]

Quartzarenites violate the uniformitarian principle in other ways, as do most sandstones. Most modern-day sands are small scale, and usually long, narrow, and thin, while sandstones in the rock record are large three-dimensional sheets.

> "It is noteworthy that most common modern sites of sand accumulation—the beaches and rivers—are linear features and the sand associated with them is confined to a narrow zone. Yet the sands of the past commonly occur in areally extensive stratiform sheets."[42]

Creation science explanations

Although uniformitarian scientists cannot explain the origin of mineralogically and texturally mature quartzarenites, nor their sometimes widespread and/or thick accumulations, creation scientists can potentially explain them by the Flood. The large volume of quartzarenite in the sedimentary rocks correlates well with the expectations of the global Flood and the massive size of the many formations.

Well-rounded, nearly pure quartz sand not from wind

Whitmore and colleagues have shown that the eolian claim for many sandstones on Earth is a mistaken uniformitarian interpretation (figure 9).[43–46] The Coconino Sandstone does not qualify as a quartzarenite since it contains too much feldspar, and the grains are not well-rounded. It was discovered that a detailed petrological analysis of the sandstone had never been made by uniformitarian scientists. Instead, researchers have cherry picked their facts to support an eolian origin. The Coconino Sandstone is, on average, only moderately sorted and only locally well sorted, with sub-angular to sub-rounded sand grains. Mica, angular K-feldspars, dolomite ooids, dolomite clasts, bedded dolomite, and dolomite cements occur within the formation. Mica would be rapidly destroyed by eolian action but not necessarily by water.[47] None of these characteristics is typical of modern eolian sands.

Figure 9. Cross-bedding within the Coconino Sandstone, a formation that lies like a knife edge on the Hermit Formation. Conventional scientists claim this contact has 5 to 10 Myr of missing rock record.

Grain frosting not necessarily by wind

The frosting of quartz sand grains is often considered a sign of rounding by wind.[48] However, frosting is more often caused by chemical weathering: "Surface textures such as frosting and rounding may be caused by different processes, including chemical dissolution and eolian abrasion."[49]

Well-rounded, nearly pure quartz sand points to powerful turbulence with chemical weathering.

So, what could have caused the abundance of well-rounded, nearly pure quartz sand in the Flood? Fast currents with powerful turbulence would explain it. An acidic early Flood environment could produce chemical weathering and leave behind a mostly high-quartz sand.[25] Or the intense mechanical weathering from turbulence could pulverize the softer minerals, leaving behind quartz and some heavy minerals.

But what about Kuenen's fluviatile experiment and Garzanti's conclusion that water cannot produce a well-rounded, nearly pure quartz sand? Both these results assume uniformitarianism. Kuenen's experiment was unnatural in some respects in that the bottom was hard concrete and not loose sand, and the grains were never in suspension because the velocities were too low, 84 cm/sec.[29] All the modern research on sand transport occurs with slow currents and low turbulence, such as Garzanti's research on transport down the Orange River and northwest along the Southwest African coast.[4]

But much greater turbulence and current velocities are capable of rounding medium-coarse sand grains. Some evidence suggests that fast transport of sand in a tidal environment in the Bay of Fundy has resulted in sand grains more rounded than their parent material.[50] Folk suggested that with enough energy, rounded sand could occur.[51,52] Rounding is mainly a matter of the grains hitting harder, which occurs much more efficiently by intense turbulence.

How do we explain its temporal change?

Once a well-rounded, nearly pure quartz sand forms, it must be deeply buried and silica cemented to become a quartzarenite. The temporal distribution shows much greater volume of quartzarenite occurs in the Precambrian, decreasing upward through the geological column. I believe this is because the Precambrian sedimentary rocks were formed in the early Flood and deposited mostly in deep basins and rifts that offered more protection from the turbulent currents. The lack of metazoan fossils in the Precambrian could be due to unique aspects of the Precambrian sedimentary rocks, such as powerful turbulence, acidic water, and hot water.[53,54] The Roraima Formation would represent a Paleoproterozoic deposition in a large basin, resulting in quartzarenite several thousand metres thick over a large area. Then the basin would have inverted with great erosion, leaving the quartzarenite as erosional remnants (tepuis).

Supporting evidence for this tremendous geological activity is derived from large impact features that occurred in both the Proterozoic and Archean.[55,56] Such impacts not only indicate that the pre-Flood/Flood boundary should be below most, if not all, Precambrian sedimentary rocks, but also impacts would cause currents fast enough and turbulence intense enough to form quartzarenites from quartz source rocks, such as the granites and gneisses of the upper crust. Such currents and turbulence would have to have been exceedingly powerful to produce such well-rounded, nearly pure quartz sand over widespread areas and of such enormous thicknesses in the Precambrian. Impact cratering is capable of accomplishing this. The sand grains in the Precambrian and early Paleozoic are coarse[57] and should round much faster. Finer sand grains usually do not round because the force of one grain upon another is not enough to chip off the sharp edges.

The massive thicknesses of many Precambrian quartzarenites would result from deposition into subsiding rifts and basins, covered by thick sediments, and cemented with silica-rich fluids. During the early Flood, the powerful currents and turbulence would have formed planar surfaces such as the Great Unconformity on the upper continental crust and on top of some basins filled with sedimentary rocks. Because of the decrease in the big impacts and the reduction in Flood energy, the Great Deposition followed.[58] This is when the Phanerozoic sediments were laid down and is probably the reason why quartzarenites of especially the lower Paleozoic are rather thin and widespread, such as the St. Peter Sandstone in the Midwest of the United States.

Implications for the pre-Flood/Flood boundary

The fact that quartzarenites are the most abundant cemented sandstone in the Precambrian and lower Paleozoic[23] suggests that there is no major sedimentological break between the Precambrian and the Cambrian, and the pre-Flood/Flood boundary must be located lower in the geological column. Besides, such large Archean and Proterozoic impacts are very unlikely to have taken place during Creation Week or between creation and the Flood. Neither is there any break in occurrence or abundance in carbonates, phosphorites, or black shales across the Precambrian/Cambrian boundary.[59] But there are raindrop imprints in the Proterozoic and late Archean. This suggests the pre-Flood/Flood boundary is much lower than the Precambrian/Cambrian boundary.[60]

Conclusions

The lack of nearly pure quartz sand with grain maturity (i.e., well roundedness) generated in present environments contrasts sharply with the well-rounded, nearly pure quartz sand, lithified to quartzarenite, in the rock record, especially in the late Precambrian and lower Paleozoic. Thus, quartzarenites violate the uniformitarian principle that the present is the key to the past.

The well-rounded, nearly pure quartz sand could have easily formed early in the Flood by powerful turbulence and fast currents, such as would occur with Archean and Proterozoic impacts. The Precambrian well-rounded, nearly pure quartz sand seems to have been deposited in deep rifts and basins formed early in the Flood. The Phanerozoic well-rounded, nearly pure quartz sands, especially in the lower Paleozoic, were deposited as thin formations over wide areas, along with other types of sediments during the Great Deposition.

The other sandstones, especially arkoses and graywackes, also display unique properties that violate the uniformitarian principle that the present is the key to the past. Since sandstones comprise 20–25% of sedimentary rocks, this means that the uniformitarian principle is incapable of explaining a large volume of sedimentary rocks.

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