HOW FAST DO ROCKS FORM?

Kurt Wise

ABSTRACT

Geologists typically maintain that the crustal rocks cannot be formed in less than millions of years. Creationists typically maintain that at catastrophic rates, all the earth's surface rocks could form rapidly. Several rock types are studied to test the validity of the creationist claim. Examples include basalts, granites, metamorphic rocks, shales, limestones and sandstones.

Non-creationist geologists typically maintain that the rocks on the earth's surface could only be created over long periods of time. It is claimed that it would be quite impossible to form all the rocks of the earth in a 6,000 year history. Taking the current rates of formation, for example, it would take many hundreds of millions of years to produce the crustal rocks. Creationists, on the other hand, typically maintain that simply accelerating the current rates of rock formation could account for the entire geologic column in a catastrophic manner. After all, if sediments at the current rate would take a million years to form, then sediments formed at a rate a thousand times as great could form in a thousand years. At a million times the current rate, only a single year would be required. This argument is appealed to by creationists, seemingly without restriction, and confirmed by isolated examples of rapidly forming rocks. If anti-creationists comment on this argument at all they usually claim that either the argument is simply absurd, or that there is no evidence that the entire geologic column was emplaced catastrophically.

What has been conspicuously absent in this discussion is a quantitative analysis of the pros and cons to the creationist position. This paper is a preliminary attempt to analyze a few of the strengths and weaknesses of the creationist argument and to suggest further directions of research. The crustal rocks can be divided into three categories: igneous, metamorphic, and sedimentary. Comment will be made on each of these categories in turn.

IGNEOUS ROCKS

Much ado in creationist circles has been made about the extensive flow basalts of the northwestern United States. These basalts formed in the recent geologic past at relatively high rates of production. Since there is no present-day analog to such extensive flow basalts, creationists claim that in the past basalt formed not only at much higher rates than at present, but also in a manner distinctly different than at present. Certainly this conclusion is true for the Pacific Northwest, but it cannot be validly extended to all areas of the earth's surface throughout the entire geologic column. Non-creationist geologists merely claim that these basalts are an example of a geographically localized area of rapid basalt formation. Vulcanism, after all, is currently a spasmodic process, operating in only a few areas of the earth's surface at a given time and only over geologically brief periods in those few areas. As a result geologists are not too surprised to recognize an example of ancient vulcanism which differs from any example we have today. In the case of the above-mentioned flow basalts, the only significant difference with the mode of formation is that these basalts occurred on the continental platform. This contrasts with most present-day basalts which occur either on oceanic islands or on the ocean floor. There appears to be no significant problem with producing continental basalts as long as the magma is allowed to flow over the continental surface rather than the ocean floor. The flow basalts of the Northwest are thus not all that unusual in type. What is most unusual is the phenomenal rates of production which have been published on this flow--far greater than any historic flow. Thus, here may be evi-

dence of higher rates of production in the past being sufficient to account for rocks we see today.

No problem, in fact, seems to be encountered forming any fine-grained igneous rock. As long as the magma is thin enough and is in contact with a cool enough environment there is no problem with producing much fine-grained crystalline rock in a short period of time. A problem does occur, however, in the formation of coarse-grained rocks, and the problem occurs in cooling. As a cooling magma passes through the freezing point of its constituent minerals, those minerals begin to crystallize. In actuality crystallization only occurs around nuclei of crystallization. If the magma isn't seeded with such nuclei, they form very slowly as the magma cools through a mineral's freezing point. As the temperature decreases the rate of nuclei formation increases. Once the nuclei exist, the rate of crystal growth about them seems to be more or less constant. If the temperature drops very slowly through the freezing point, only a few nuclei will form, and the crystals forming about them will grow to large size. The magma will be completely depleted of this mineral before more nuclei can form. If, on the other hand, the magma cools rapidly through the freezing point of a component mineral then many nuclei form before the crystals grow enough to deplete the magma. As a result, slow-cooling magmas tend to produce large crystals and fast-cooling magmas tend to produce fine-grained igneous rocks. Mineral composition and water content can affect the actual rate, but the relationship remains the same.

Since they indicate rapid cooling, creationists should have no trouble explaining any fine-grained igneous rock. Non-creationists, however, claim that much time is required to create the coarse-grained igneous rocks. Winkler (1949) felt that a "mean cooling velocity" on the order of 0.2 degrees Centigrade per hour would produce the largest crystals. Since all the minerals in most igneous rocks would be crystallized over a temperature range of 200 degrees C, 1000 hours of cooling would be required to crystallize a coarse-grained igneous rock. As a result, only a month and a half of cooling is required to produce a granite. This is true, however, only if the rate of cooling is as high as this. The problem with many intrusive magmas is their volume. Many of them are so large as to make their cooling impossible in only a few thousand years.

The actual relationship between the size of an intrusion and the time it takes to cool is a very complicated differential equation. Assuming that the temperature of the medium about the magma is zero degrees Centigrade, a close approximation of this equation can be made. The time of significant cooling at a depth L into a magma is equal to the square of L divided by the thermal diffusivity of the magma. The granite batholiths of the White Mountains of New Hampshire are kilometers in diameter, some being more than 10 kilometers in diameter. The thermal diffusivity of granite is about 0.005 cm/sec. Thus, a 10 kilometer diameter batholith would take much more than 100,000 years to cool by conduction.

A significant problem for creationists is thus how to rapidly cool large magmatic batholiths. Robert Gentry in studying Precambrian granites, may well be justified in appealing to the Creator to explain evidence of rapid cooling, but it is not possible to use this argument in the White Mountain granites. These granites intrude into and metamorphose sediments of the Cambrian, Ordovician, Silurian and Devonian. These granites were thus emplaced after what are generally considered flood sediments by creationists. Although convection can accelerate cooling, once crystallization becomes advanced convection becomes impossible. There is no other mechanism known to the author which can account for the rapid cooling of granite batholiths. Creationists are encouraged to consider this subject for future research. Firstly, a careful examination of the rate of crystal growth in igneous melts is needed. This is necessary in order to confirm or deny the claim made here that it is possible to produce all igneous rock types in the time frame of creationism. Secondly, an in-depth study of the rate of cooling of large magmatic bodies must be done to determine if there is some mechanism for rapid cooling which would allow post-creation granite to cool.

METAMORPHIC ROCKS

It is commonly felt by non-creationist geologists that the existence of metamorphic rocks is proof of the great antiquity of the earth. It is not, however, the rate of metamorphism which indicates long ages. It seems that any metamorphic reaction can be reproduced in the lab. Each of these reactions can be made to occur in less than a few weeks. The higher the temperature and/or pressure, the faster the reaction. It turns out that any reaction which involves more than about 300 degrees Centigrade can be reproduced in the course of a single day or less. Chemical equilibrium in the process of metamorphism is thus rather quickly reached once the thermal conditions are achieved. It is, however, rather difficult to achieve those conditions.

There are two major types of metamorphism. Regional metamorphism involves high temperature and pressure and contact metamorphism involves only elevated temperatures. Contact metamorphism is basically the baking of rocks with the intrusion of a magma. The earliest reported example of a contact metamorphic zone around an igneous intrusion in the United States was made by Barrell (1907). The pluton is located in Marysville, Montana. Around a granodiorite intrusion with an average radius of about a kilometer is a kilometer-wide zone of metamorphosed sediments. By the above arguments the pluton should have taken something like 10,000 years to cool, and the sediments should have taken something like 10,000 years to heat up in order to undergo metamorphism. Here not only do creationists have trouble explaining how the magma cooled so quickly, they also have trouble explaining how the surrounding sediments could have been metamorphosed rapidly.

However, it is not in the formation of contact metamorphic rocks that the most common metamorphism objections to creationism occur. Regional metamorphic rocks have been subjected to high pressures as well as high temperatures. This, in addition to the fact that they are always found over areas of hundreds of square kilometers, has led geologists to believe that regional metamorphism occurs when the parent rocks are buried to great depth. At current rates of sedimentation the burial process itself would take many millions of years. Creationists, however, have suggested a mechanism for more rapid burial. To increase the rate of sedimentation to catastrophic levels during Noah's flood or some such similar catastrophe, burial can be accomplished in days or months. The biggest problem, however, lies again in the problem of heat. Rapid burial beneath many kilometers of sediment produces instantaneous pressure increases, but once again it takes too much time to heat the sediment. In fact it would take many millions of years to heat up sediment buried 20 kilometers beneath the surface.

A further problem with the granites found in New England and elsewhere is the source of the magmas for them. Granites are formed by partially melting crustal rocks. This is conventionally thought to be a result of metamorphism. Upon sufficient burial (more than 30 kilometers) the temperature is sufficient for melting of the sediments. Those molten sediments then rise to the surface, becoming thus emplaced as granite plutons. Once again, however, the time it takes to heat such a rock to a melting temperature of 600 degrees Centigrade is too long for creationism to accept.

SEDIMENTARY ROCKS

There is an average of approximately one mile of sediment over the surface of the earth (Ronov, 1968). Non-creationist geologists must maintain that all the sediments on earth were formed from igneous rocks. In the weathering of igneous rocks not only are sedimentary rocks formed, but also a few byproducts such as sodium and chlorine. If all the sodium currently dissolved in the ocean and contained in the sediments is assumed to come from the decomposition of igneous rocks then it would have also produced the amount of sedimentary rock that is observed on the earth (Kuenen, 1941). If the same calculation is done for chlorine, it should have produced four times as much sediment as is now observed on the earth (Garrels and MacKenzie, 1974). The error in each of these calculations is probably considerable, perhaps a factor of five or so. As a result, geologists generally hold this as evidence in favor of the contention that all the sediment on the earth was derived from igneous rocks. Yet another piece of evidence comes in determining what ratio of shale, sandstone, and limestone would be produced from the average igneous rock. Eighty percent of the sedimentary package would be shale, 11% would be sandstone and 9% would be limestone (Mead, 1907). The ratio actually observed in the rock record is something like 65% shale, 15% sandstone, and 20% limestone (Garrels and MacKenzie, 1974:247). Although there is more sandstone and limestone than predicted by weathering igneous rocks alone, the ratio is close enough to lend further support to the contention that all the rocks are derived by weathering of igneous rocks.

Creationists, on the other hand, do not have to derive all sediments from igneous precursors. Much or all of the sediment may actually be reactivated sediments from the creation. The maximum amount of igneous rock weathered is that which would have to be weathered to produce the current amount of shale on the earth's surface. The current sedimentary package has a mass of 2.2×10^{21} kilograms. Sixty-five percent by weight (or 1.4×10^{21} kg) is shale. Since five grams of igneous rock produces about four grams of shale by weathering, 1.6×10^{21} kg of igneous rock would have to be weathered to produce the current amount of shale. This amounts to about 4.8×10^{8} cubic kilometers, or pretty close to a kilometer of igneous rock over the entire surface of the earth. Pulverized feldspar put in a warm acid solution can produce at least some of the weathering products in only a few hours. However, as Garrels and MacKenzie (1974) point out, the most important experiments have not been done—namely taking an igneous rock and observing the rate at which that rock weathers into all the sedimentary endproducts. It does still appear as if at least a couple of the weathering products (e.g., smectite) may take an

extended period of time to form. It is also necessary for creationists to determine whether the Flood could have supplied enough physical weathering to pulverize that much rock. It should also be determined whether there could have been enough acidity--even with the dissolution of much atmospheric carbon dioxide--to chemically erode that much rock in a short amount of time. This type of calculation, however, gives only a maximum amount of igneous rock eroded in the flood. If this much igneous rock was broken down in the flood this type of argument is critical. If, on the other hand, our current shale is simply reactivated antediluvian sediments creationism is not to be bothered by so much shale.

Whereas a creationist may not necessarily have to worry about the origin of sediments, they must certainly deal with the deposition, lithification and diagenesis of those sediments. For nearly any sedimentary rock, local rates of deposition can be found that indicate the possibility of rapid deposition. A single storm can transport and redeposit many meters of any type of clastic sediment. Fresh-water springs, such as at Sarasota, New York, and in Yellowstone National Park, can precipitate inches of limestone or silica in a single day. It may turn out that there is not a single type of sediment which cannot be deposited catastrophically.

Rates of lithification are also a concern for creationists. The literature, however, is filled with examples of rapid lithification. Rapid carbonate lithification occurs on the ocean bottom, on reefs, on beaches (beachrock), in backshore sand dunes (aeolinite), and in freshwater rivers and springs (cayrock). Beachrock is the best example of this. A cannon (Reclus, 1873), a battery (Fairbridge and Teichert, 1948), barbed wire (Straaten, 1957), tin cans (Puri and Collier, 1967), beer bottles (Scoffin, 1970), and Coca-Cola bottles (Fairbridge, 1963) have all been found cemented solidly in limestone. Beachrock lithification can be simulated in the lab in a few hours and can be shown to occur in nature in less than a few weeks. Further investigation may allow us to understand how large amounts of carbonate could form and lithify rapidly. It may again turn out that all types of lithification can occur in short periods of time.

SUMMARY

Much research in creationism is still to be done. Rates of crystal growth in melts need to be examined to determine if all igneous rock types can be produced in only a few thousand years. Much study needs to be done on thermodynamics of earth materials. Some mechanism for rapid cooling and heating of rocks must be found in order to allow for the formation of metamorphic and coarse-grained igneous rocks in a creationist time frame. The thermal diffusivity of rocks should be examined to determine if in the past it may have been significantly greater. Otherwise many of the crystalline rocks on our earth indicate an earth much older than a few thousand years.

Concentrated study of the geochemistry of the earth's sedimentary rocks may lead us to a greater understanding of the antediluvian world. We may be able to determine how much dissolved sodium and chlorine were in the pristine seas, and how much sediment existed before the creation of man. Furthermore, we may be able to determine if all our sediments could actually be formed in only a few thousand years. Creationists need to study much about the deposition and lithification of sediments. It seems possible that under catastrophic conditions any sediment can be rapidly deposited and rapidly lithified. For example, an understanding of the formation of beachrock and allied limestones as well as the diagenesis of carbonates may well lead us to an understanding of how all the limestones of earth came to be.

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DISCUSSION

Kurt Wise has written an excellent paper summarizing both evolutionists' and creationists' views and predictions on how rocks form. Kurt has read widely, very scholarly handled the subject in a basic overview, critically evaluated both views, and presented even new approaches which deserve exploration. Much study went into this synthesis. Two specific suggestions:

1) Use the words "stratigraphic record" instead of "geologic column,"

2) Review recent geologic literature on rapid production of granitic textures in laboratory experiments.

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Admittedly the author is attempting to survey a very broad subject and to highlight problem areas for further research and study. For doing this he is to be congratulated.

The extensive flow basalts of the Pacific Northwest, U.S.A., are not unique—even eastern Australia shows evidence of extensive violent continental volcanism in the past. On the question of quantifying the cooling of magmas, surely it is a bit unwise to quote a 1949 reference on crystallization of basaltic magmas in dikes and then apply it to granite batholiths! And how does one directly and accurately measure the thermal diffusivity of magmas? A reference for the complicated cooling equation would be a help.

Kurt is quite right in saying that geologists believe regional metamorphism occurs when the parent rocks are buried to great depth, for no one has observed those processes. However, another researcher has presented an alternative, of which Mr. Wise should be aware. Prof. Richard Stanton of the University of New England, Armidale, Australia, writing in the Proceedings of the Australasian Institute of Mining and Metallurgy, No. 202, June 1982, pp. 11-32, suggested with detailed evidence to support his case, that the miles-wide zones of regional metamorphism may be totally unrelated to temperature and pressure conditions, but may in fact be completely dependent on the chemical nature and mineralogy of the precursor sediments. Furthermore, those temperature conditions necessary for numerous mineral reactions may not be due to deep burial at all, but to circulating hydrothermal fluids, primarily superheated water.

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Conventional views on the formation of igneous, metamorphic and sedimentary rocks are all influenced by Hutton's gradualistic rock cycle, and involve long timescales. It is important for creationists to distinguish real problems from those which arise from a conflict of paradigms. Probably most of the difficulties mentioned by Mr. Wise belong to the latter group.

Conventional geology consistently overlooks the grand scale of processes in the past. Modern analogues are so dominant in the thinking of geologists that scaling factors and alternative interpretations are rarely investigated. Creationists must not make this mistake.

Water plays a vital role in diluvialist thinking, and its presence as porewater appears to be relevant to the problems of igneous and metamorphic rocks mentioned by Mr. Wise. Convective cooling by water of large magmatic bodies provides a mechanism for extremely rapid cooling and may also be relevant to the problem of regional metamorphism.

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CLOSURE

Thanks go to the reviewers and conference participants for the many excellent comments, suggestions, and discussions. Dr. Austin's resistance to using the term "geologic column," is understandable because with the use of the word comes much unwanted meaning. The geologic column refers not just to the stratigraphic record, but the interpretation of that record through superpositional stratigraphy, etc., to construct an imaginary stratigraphic

column. This column is more or less arbitrarily divided into smaller segments and absolute dates are then superimposed to finally construct the geologic column. Since this author also rejects the absolute dates of the geologic column but believes that there is still much that is useful in the interpretation of the strata into an imaginary column, perhaps it would be better to use the term "stratigraphic column."

There is no doubt, as Dr. Austin suggests, that more research should be done on reviewing geologic literature on artificial production of granitic textures. Samuel E. Swanson (1977, Relation of nucleation and crystal-growth rate to the development of granitic textures, Am. Mineralogist, 62:966-978), for example, has successfully formed feldspar and quartz crystals several millimeters in diameter in only a few days time by cooling a melt. This lends support to the creationist prediction that it must be possible to form granitic textures in short periods of time (<10,000 years).

A good reference for the heat conduction of solids in Carslaw, H.S., and J.C. Jaeger, 1959, Conduction of Heat in Solids, Oxford Univ., 510 p. As for measuring the thermal diffusivity of magmas, that is often a difficult and indirect process. To know the thermal diffusivity, one must know the density, specific heat, and thermal conductivity. Each of these can be experimentally measured but it is nearly always impossible to measure it in actual field position (for example 5 kilometers down at 1200°C!). It is personally doubted that the errors of measurement will significantly affect the results, but it may be worthy of further study.

Dr. Snelling's mention of Stanton's research is not without precedent or companion. There is a general acknowledgment in metamorphic geology that the old idea of large-scale chemical diffusion may not ever be the case. There is apparently no firm evidence that diffusion occurs over distances of centimeters, let alone kilometers. This lends strong circumstantial evidence for "regional" metamorphic rocks being direct derivatives of the original rock or sediment. This research has some very interesting prospects for creationism. Classical regional metaphoric theory made the inference of original rock composition nearly impossible. It may be possible with new theory to understand the metamorphic precursors and thus better understand the geologic processes preceding metamorphism.

Both Dr. Snelling and David Tyler mention a very important further consideration--hydrothermal activity. The apparent difficulties of cooling granitic magmas, heating metamorphic zones, and cooling ocean floor in only a few thousand years is that it cannot be done naturally by conduction or radiation. That leaves only convection. These rocks are too cold to convect themselves, but water may be able to be convected through them. This water would be able to convect an enormous amount of heat very quickly, maybe even within the creationist time frame. This needs to be determined theoretically and then verified by observation. Unless the heated water happens to have an identical chemical composition to that of the rocks (extremely unlikely) the water will cause an alteration of the rock. Extensive hydrothermal activity would be evidenced by many mineralogical and isotopic signatures [see Ellis, A. J., and W. A. J. Mahon, 1977, Chemistry and Geothermal Systems, Academic Press, NY, 392 p., and Walther, John V., and the Bernard J. Wood (eds.), 1986, Fluid-Rock Interactions During Metamorphism, Springer-Verlag, NY]. Thus, when in theory hydrothermal convection is the only natural process which can cool a particular pluton, then a hydrothermal fingerprint can be predicted for that pluton. This sort of predictability would be invaluable in creationist research.

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