Remarks by the President

Recently many evolutionists not only have been distorting the classical expression of the scientific method by referring to evolution as a "fact" but also they have been chastising creationists by saying they are religionists masquerading as scientists in an effort to intrude religion into science. The presupposition of these evolutionists is that science excludes religious considerations and deals only with observations of matter. But, should not the best science deal with all of reality? Many of the so-called anti-creationists themselves have what might be called an underlying agenda, and that is to promote a secularistic or naturalistic position that excludes recognition of supernatural power.

However this may be, it is true that creationists recognize a supernatural creator. This creator could be either a non-personal god (of Plato and Aristotle) or the personal Judeo / Christian God. But this whole issue of naturalism vs. supernaturalism is only one side of the coin; the other is mechanistic being based upon sensory data (facts) obtained by observing nature. The two mechanistic positions have been termed the macroevolution model and the abrupt appearance model. The former perception is that of a single tree with extinct and extant forms of life on their branches; whereas for the latter there is a forest of separate physically-unrelated trees (possibly 7,000) each representing a "kind." Most creationists do not hold "fixity of species" but rather that there has been some diversification within the kinds.

Members of the Creation Research Society believe in a supernatural personal Creator-God; and they also hold that the preferable interpretation of data from nature is the abrupt appearance model. Information about both models legally can be presented in classrooms of the United States, and it is our contention that responsible science teachers will be informing students of the difference between "macroevolution" and "abrupt appearance" with strengths and weaknesses of both positions.

Wayne Frair.

Editorial Comments

In preparing these remarks, I did a literature survey of articles and notes in the *Quarterly* that were the result of field or laboratory research work. There are 103 entries and this does not include many original projects of research primarily of the library type. Therefore the charge that creationist scientists do not perform research work is false.

It is amazing that scientists who are creationists do any research at all! Creationists do not have access to Federal money taken from the taxpayer's pockets that is available to evolutionists. Often the companies or schools where creationists work are not sympathetic to their views so their work must be extracurricular. Only dedicated creationists would expend the herculean effort necessary to do research beyond their vocational activities.

Possibly some may think that teaching in a Christian school would allow a person time to perform research. Generally the massive teaching loads, administrative duties, outside speaking schedules and other required activities leave the creationist very little time for his own projects. So you can understand why it is remarkable that any research has been done. While evolutionists have only to climb foothills to do their research, creationists must scale mountains.

Some of the articles in this issue are the culmination of years of work in the Grand Canyon area. Also many of you could help the Research Committee by collecting wildflowers in your area for our herbarium. You may have research opportunities within your area. Why not do a preliminary study and write a letter to the editor? The Research Committee needs your help, both financially (Laboratory Project) as well as some of your expertise in doing the work.

Emmett L. Williams, Editor

THE BIOLOGICAL ISOLATION OF SHIVA TEMPLE

John R. Meyer* and George F. Howe**

Received 20 December 1986 Revised 29 June 1987

Abstract

Geographical isolation is an important constituent of most scenarios of the evolutionary origin of species. In an earlier study, Anthony (1937) compared mammals of Shiva Temple with those of the North Rim of the Grand Canyon, and concluded that isolation on Shiva was incomplete since the two populations demonstrated no significant differences. We attempt here to assess the degree of biological isolation between Shiva Temple and the nearby North Rim of the Grand Canyon. Based on limited direct observation of selected environmental variables, analysis of vegetation, and study of the known distribution of small mammals, we conclude that for some small mammals, Shiva Temple is probably biologically isolated from the North Rim. The implications of these findings are discussed in terms of the creationist concept of a recent and catastrophic origin of the Grand Canyon. Key Words: Grand Canyon, Shiva Temple, geographical isolation, biogeography, speciation, Anthony.

*John R. Meyer is Professor of Biology at Baptist Bible College, Clarks Summit, PA. He is Chairman of the Research Committee of the Creation Research Society and receives his mail at R.D. 1, Box 101A, Clarks Summit, PA 18411.

**George F. Howe is Professor and Chairman, Division of Natural Sciences and Mathematics, The Master's College, Newhall, CA, He is the Director of the Creation Research Society's Grand Canyon Experiment Station. He receives his mail at 24635 Apple St., Newhall, CA 91321.

Introduction

In September of 1937, Harold Anthony, mammalogist with the American Museum of Natural History, led an expedition to the top of Shiva Temple in the Grand Canyon (for details see Meyer, 1987 and Anthony, 1937). Figure 1 is a photograph of Shiva Temple from the North Rim. He intended to examine the supposedly isolated populations on top of Shiva Temple and compare them to similar populations on the adjacent North Rim. After close examination of mammals from both localities, Anthony concluded that no significant differences existed, at least in the morphological characteristics which could be evaluated at that time.

Failure to find detectable differences in the two faunal groups was attributed by Anthony to incomplete isolation of Shiva Temple from the North Rim and to a recent origin for whatever incomplete isolation barriers might currently exist. Suggestion of evidence of incomplete isolation came not only from the observation of deer antlers and human artifacts on Shiva but also from the philosophical incompatibility of the concept of complete isolation with failure to observe evolutionary changes. The isolation of Shiva Temple for small mammals, however, may be much more complete than Anthony realized. McKee (1937) has observed that there may well be strict isolation:

> Almost any animal is able to ascend Shiva Temple; but few, if any of the small forest dwelling species . . . do because of the desert conditions which prevail below. Thus, the climatic belt in the area below Shiva represents as complete a barrier for some species as an ocean body.

The nature and extent of these climatic factors along the most likely migration route to Shiva (the saddle between the northeast base of Shiva and the adjacent North Rim, which we shall call "Shiva Saddle") have never been directly quantified. Although the fauna of the Kaibab Plateau and the isolated top of Shiva have been studied—see Anthony (1937), Hoffmeister (1971), and Rasmussen (1941)—no evaluation of existing data has been performed to assess the likelihood of particular small mammals existing on the Saddle itself. Thus, the degree of isolation of Shiva Temple is still an open and important question to ecologists and population biologists interested in the biogeography of the Grand Canyon vicinity and the genetics of isolated populations.

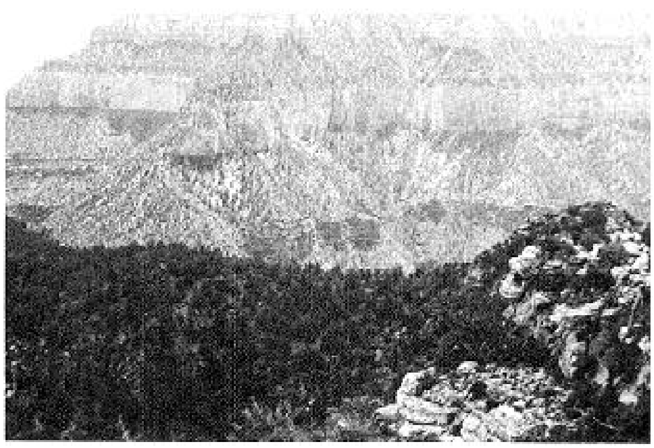

Figure 1. Photograph of Shiva Temple from the North Rim. The ridge leading out to the Saddle is seen in the foreground. The Anthony expedition reached the top of Shiva by following the ridge and then descending into the Saddle. They then ascended the talus slope seen in the center of the left third of the photograph. Final access to the top was gained at about the center of the rim.

Our purpose in this study is to prepare a preliminary evaluation of the degree of isolation of Shiva Temple using direct observation of vegetation and selected climatic variables along with known habitat preferences of the small mammals of the Grand Canyon area. Implications of these data will be discussed in relation to the failure of Shiva Temple mammals to demonstrate significant differences from their North Rim counterparts.

Methods

Aerial reconnaissance photography: On May 31, 1979, we chartered a single-engine Cessna for survey of Shiva Temple. The right-hand doors were removed and Shiva was circled four times at different altitudes to allow nearly 100 photographs of the vegetation and general topography of the area. Figures 2 and 3 are aerial photographs of the top and sides of Shiva.

Data collecting stations: Measurements were made on July 2 and 3, 1985. North Rim measurements were started at 3:00 p.m. local time and were taken hourly until 3:00 p.m. the next day. Saddle measurements were started at 3:00 p.m. but were terminated the next morning at 5:00 a.m. due to declining water supplies and the need to finish the rigorous climb back to the North Rim before the heat of the day arrived.

On Shiva Saddle, data were gathered at 6300 feet at two stations, one shaded and the other unshaded. Five stations were established on the North Rim at 7650 feet. North Rim station 0 was located in an unshaded area a few feet from the edge of the Rim itself. Station 1 was located a few feet away from station 9, under the shade of a juniper tree. Stations 2, 3, and 4 were located at 10, 20, and 30 yards, respectively from the edge of the Rim in unshaded areas. Data are reported here only for stations 1 and 4 since they are shaded and unshaded areas, respectively, on the Rim which are comparable to similar areas from the Saddle.

Soil Temperatures: These were measured using standard mercury-type soil thermometers with brass probes. These instruments provide an average temperature of the first five or six centimeters of topsoil.

Relative humidity and air temperature: These data were gathered at all stations using two matched, motor-driven Psychrodyne psychrometers. Relative humidity readings were converted to vapor pressure deficits to reflect the actual water stress placed on organisms, as the vapor pressure deficit is a measure of how much more water the air can extract from nearby plants and animals. Vapor pressure deficits were corrected for the 1350 feet difference in altitude between the Saddle and the Rim. Air temperature was taken as the psychrometer dry bulb reading.

Plant identification: While hiking along trails and cross country a list was kept of plants seen at various locations. The list is by no means exhaustive as we could carry only a limited number of plant taxonomy books in our packs and we had no permits to collect plant specimens for more detailed herbarium study.

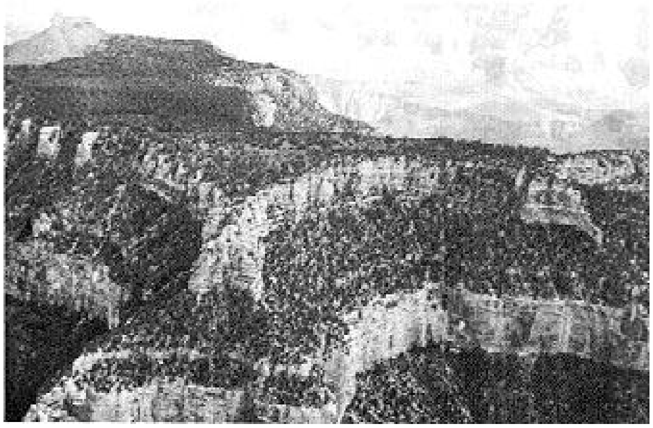

Figure 2. Aerial photograph of Shiva Temple. The northwest corner of Shiva is in the foreground and the direction is to the southeast. The upper reaches of the inner gorge of the Colorado River can be seen just above the edge of Shiva, left of center.

The identifications are thus "field calls" carried out between periods of hiking and camping.

Results

Soil temperatures for shaded and unshaded stations 1 and 4 of the North Rim and the shaded and unshaded stations on the Saddle are shown in Figure 4. Generally, soil temperatures at the shaded Saddle station were as much as 13°C higher than the shaded Rim station in the early afternoon. The unshaded Saddle station was up to 12°C higher than the unshaded Rim station at the same time (although there was one unexpected reversal of this at 3 p.m.) Soil temperatures from both locales, whether from shaded or unshaded areas, tend to converge during the night.

Vapor pressure deficit calculations derived from relative humidity measurements are displayed in Figure 5. At all times of measurement, the vapor pressure deficit was higher in the Saddle than along the Rim. These differences ranged from a maximum of nearly 0.4 inches of mercury at 6:00 p.m. to a minimum of less than 0.1 at 4:00 a.m. Changes in vapor pressure deficit closely reflect the prevailing *air temperature* as shown in Figure 6. At all times of measurement, air temperature was from 1 to 6°C warmer on the Saddle.

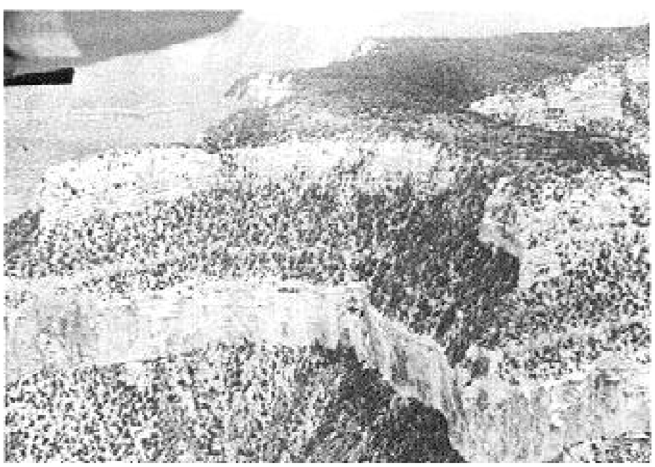

Figure 3. Aerial photograph of Shiva Temple. The western edge is in the foreground and the view is to the northeast. The north wall of the Grand Canyon is seen in the upper left, just below the wing tip.

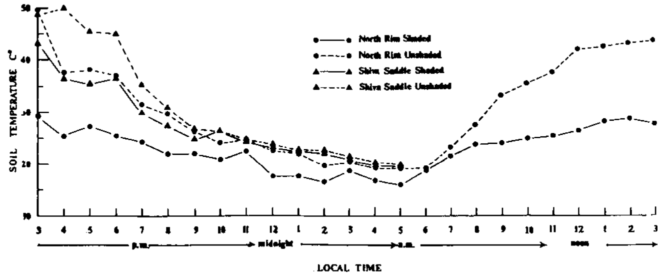

Figure 4. Comparison of shaded and unshaded soil temperatures for the edge of the North Rim and Shiva Saddle area.

General vegetational distribution as derived from both aerial photographs and ground-based observations are presented diagrammatically in Figure 4. Detailed species lists for the areas under study are given in the Appendices A and B. The Saddle area is populated almost exclusively with pinyon pine and juniper, while the sun-exposed south walls of Shiva, the ridge and the North Rim are composed of pinyon pine, juniper and shrubland. The top of Shiva Temple (see Figure 7) and the lower reaches of the Kaibab Plateau at the North Rim contain heavy homogeneous stands of Ponderosa Pine. Though not shown in Figure 8 because of the fine resolution needed, the southern edge of the top of Shiva and the North Rim also exhibit pinyon pine, juniper, and shrubland vegetation in a narrow strip of a few dozen or so yards in width. Aerial photographs provide evidence that the distribution of plants for Shiva Temple is similar to that of the North Rim.

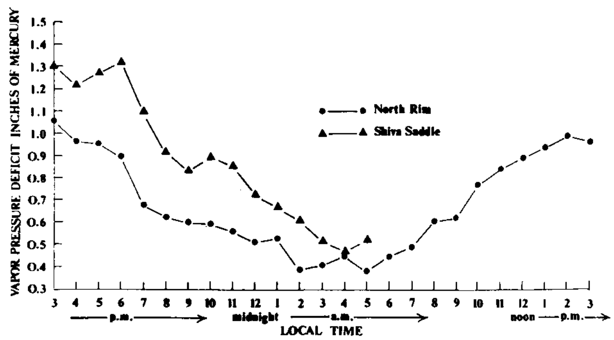

Figure 5. Comparison of vapor pressure deficit for the North Rim and for the Shiva Saddle area. Data are corrected for the 1350 feet difference in altitude between the two areas.

Discussion

Physical features: In considering the possible biological isolation of Shiva Temple, it is necessary to review the physiography of the area. Figure 9 is a cross section of the Shiva Temple/North Rim area and gives a general picture of the topography and geology. The edge of the Kaibab Plateau at Shiva Expedition Point is very nearly the same altitude as the top of Shiva, with the two areas separated by nearly two miles horizontal distance. In traversing the area from the North Rim it is necessary to descend approximately 350 feet below the Rim to a ridge which runs nearly one-half mile. A 1000

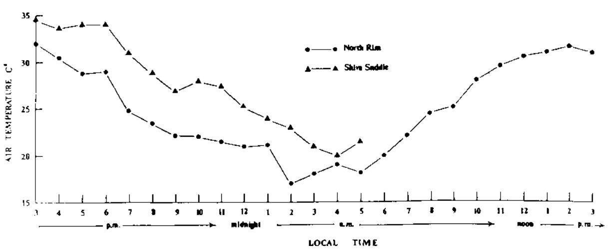

Figure 6. Comparison of air temperature for the North Rim and for the Saddle area.

additional feet descent from the south end of the ridge is required to gain access to the three-quarter mile long Saddle. From here the top of Shiva towers 1350 feet overhead and can be reached only by ascending a steep talus slope through the Hermit Shale strata, a near-vertical pitch through the Coconino, a series of several shorter talus slopes through the Toroweap and another nearly-vertical pitch up the Kaibab to the top. It will be noted, however that there are areas in the Kaibab and Coconino where the pitch is broken and it is primarily through these areas that access is gained to the top (see Figure 10).

The Saddle is narrow and flanked on either side by nearly vertical walls which descend at least another 1000 feet to the basins below. Compared to other ridges separating side canyons in this vicinity, the Saddle is small in area and remarkably flat. Thus, it appears to receive not only the direct heating from the sun throughout most of the day (except when the sun is the lowest in winter when it may be shielded by Shiva Temple for a few hours in mid-afternoon) but also the heat of rising air from the reaches below—see Malm (1974) for a more detailed description of air movements in the Canyon.

Physiography of the area: Shiva, like the Kaibab Plateau from which it is separated is capped with Kaibab limestone. This highly porous layer results in the complete lack of standing water on Shiva; and except for the tiny seasonal streams, it is almost completely lacking on the North Rim. Rasmussen, (1941) reports that standing water on the North Rim is rare and is usually found associated with sink holes which have become sealed by silt. He indicates, "They are practically the sole source of water for all animals. They are not abundant, and it is often several miles between them." (p. 234) Thus, they are not accessible to many of the smaller mammals with limited home ranges.

Figure 7. Aerial photograph of Ponderosa Pine forest on Shiva Temple.

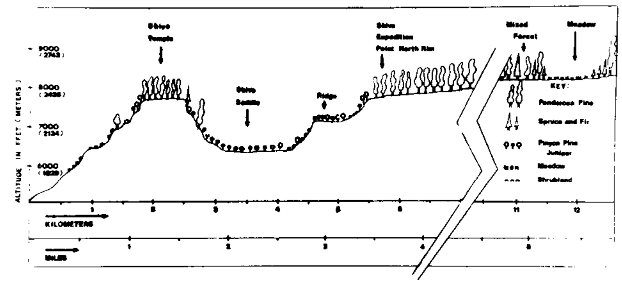

Figure 8. Cross-sectional profile through the Shiva Temple/North Rim area indicating dominant vegetation. A two-fold vertical exaggeration is used. The profile is approximately north/south in orientation with south on the left.

The physiography of the area heavily influences climate and this in turn controls vegetation. Thus, the limited, preliminary climatological data we have obtained show major differences in the environment for 24 hours or less, between the Saddle and the Rim, and the vegetation reflects this same differential. The contrasts in climatological data and vegetational observations for the Saddle and North Rim are highly consistent with the concept of a significant climatic barrier on the Saddle. Thus, small mammals which are restricted to the Ponderosa Pine forest of the North Rim would likely find the Saddle inhospitable, precisely as previously noted in the Shiva Temple file in the Grand Canyon National Park Research Library.

Vegetational differences: Although our plant list is preliminary and limited primarily to those species which yield to field identification, several important patterns emerge from the data. The pinyon pine and juniper forests of the ridge and the Saddle between Shiva Temple and the North Rim differ markedly in plant species composition from the two Ponderosa Pine forests they separate—see Appendix A. The pinyon and juniper stands have much bare rock and soil between scattered trees and are characterized by a desert component of plant life which is largely missing at both Shiva and the North Rim.

Only 16 of the 75 plant species noted in the Appendix were seen at both localities (Shiva Saddle and North Rim). Thus, most of the plant species we observed (59

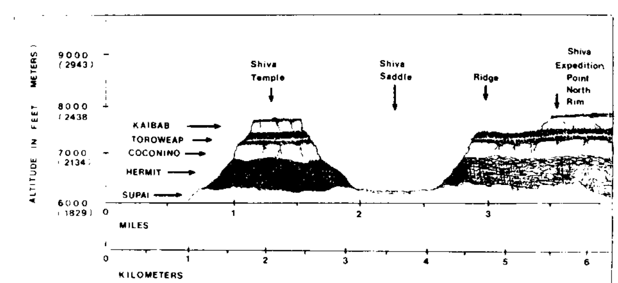

Figure 9. Cross-sectional profile through the Shiva Temple/North Rim area showing correlation between geological strata and topography. A two-fold vertical exaggeration is used. Profile is approximately north/south in orientation with south on the left.

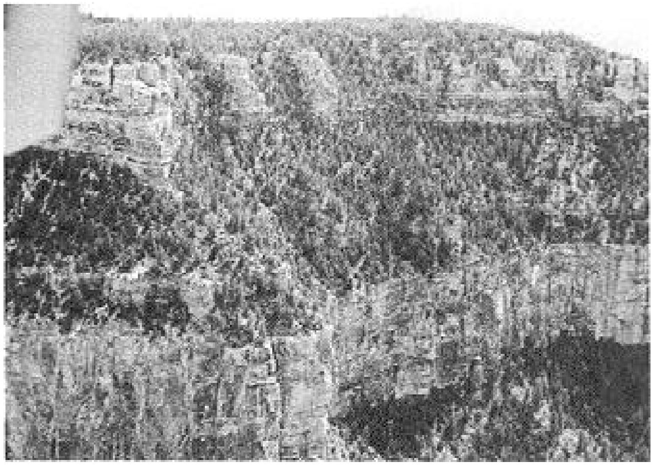

Figure 10. Aerial photograph of northeast corner of Shiva Temple. The final approach to the top for the Anthony expedition was apparently up one of the steep talus slopes along the left edge of the rim.

out of 75) were found at either the Ponderosa forests above or the pinon pine-juniper Saddle below, but not both. This difference between the plant species present in the two areas appears to provide an additional obstacle to gene flow between mammal populations of the Saddle and the Rim.

Our aerial photographic reconnaissance of Shiva Temple provides evidence that its vegetation is strikingly similar to that of the adjacent North Rim. The southern and southwestern parts of Shiva are apparently recipients of warm, dry air ascending along its cliffs and spilling over a short distance before ascending farther. Thus, the climate along these edges is apparently considerably more xeric than the rest of Shiva. This is evidenced by the dominant pinyon pine and juniper, with some scattered shrubland in this area. An identical situation exists along the edge of the North Rim, as discussed by Golike and Howe (1975).

As one approaches the Rim from the north or main part of the Kaibab Plateau, there is a striking vegetational change. The homogeneous, mature Ponderosa Pine forests begin to fade into scattered stands composed of stately individuals, punctuated by increasing areas of pinyon pine and juniper trees. Within eight to ten yards of the Rim, distinctively xeric desert type plants such as cliff rose and pin cushion cacti, begin to appear and the Ponderosa fade out of the picture. Thus, within a few hundred feet as one approaches the edge, one passes through a vegetational change equivalent to ascending several thousand feet on a more gentle slope. Such a zone would otherwise support much more mesic vegetation like Ponderosa Pine or even aspen. This phenomenon is known as "zonal suppression"—see Golike and Howe (1975). Zonal suppression and the difference of vegetation on the Saddle as compared to the North Rim may present barriers to animal migration.

Mammalian biogeography: Is the climatic barrier sufficient to isolate the mammals of Shiva Temple and prevent gene flow between it and the North Rim? For some mammals the answer is clearly no. Appendix B displays the biogeography of mammals of the area as obtained from several different sources. From this it can be seen that a number of small mammals of the canyon area are equally at home in the vegetational associations of the Saddle, the North Rim, and Shiva. Many of these animals are at home on rocky slopes and can easily work their way up rock crevices. All that is needed is time before at least some of them, over a period of generations, could work across the Saddle and up Shiva. While this would reduce gene flow, it could not be claimed to completely stop it.

On the other hand, there are several species of small mammals which are at home in the Ponderosa Pine forests but do not frequent areas composed of the vegetation seen on the ridge or the Saddle itself. As seen from Appendix B, these would include the Bushy-tailed Wood Rat *(Neotoma cinerea)*, the Brush Mouse *(Peromyscus boylii)*, and the Canyon Mouse *(Peromyscus crinitus)*. At least two other species appear to be residents of the rim rock area along the edge of the Kaibab Plateau and along the edge of Shiva Temple. These would include the Pinyon Mouse *(Peromyscus trui)* and the Cliff Chipmunk *(Eutamius dorsalis utahensis)*. Furthermore, the Kaibab squirrel *(Sciurus aberti kaibabensis)* is absent from both the Saddle and Shiva Temple. The Saddle is clearly a barrier to this mammal because it is an obligate feeder on cones and twigs of Ponderosa Pine trees which are not found on the Saddle (see Meyer, 1985 for a detailed discussion of the biology of the Kaibab squirrel).

Thus, it is quite likely that these mammals are not on the Saddle and they would find the environment of this area too harsh to make a crossing. It might be asserted here that some breakdown of isolation could occur since man, raptors, or even tornadoes might have dropped individual specimens of these otherwise isolated animals. While this is possible, we believe that such events would be quite rare and would not likely constitute a consistent mechanism for significant gene flow between small mammal populations on the North Rim and Shiva Temple. Such mechanisms have clearly failed in the case of the Kaibab squirrel which does not inhabit the mature Ponderosa Pine forest on Shiva. Furthermore, some evolutionists appear open to the possibility that an occasional, limited influx of genes from the parent population could enrich genetic diversity within the isolated population and enhance speciation. For example see Stansfield, 1977.

For the above noted mammals at least, we would predict that gene flow across the Saddle is highly limited or totally absent. For these species it appears that Shiva Temple is, indeed, an "Island in the Sky," as it was originally entitled by Anthony; but its relatively recent isolation from the North Rim has been insufficient to allow even the small changes in characteristics which would be well within the "kinds" of the creationist model. The situation is thus much like that of the Kaibab and Abert squirrels which have supposedly been separated by several million years but which show differences only in tail and belly coloration for some of the individuals in each population—see Meyer (1985) and Williams (1986) for details.

Additional Support of the Model

A possible way of gaining considerable, additional information on this intriguing problem would be to make a more detailed vegetational analysis of the area and to collect additional environmental data at different times of the year. More importantly, direct trapping of the mammals on the saddle itself could be used to ascertain the biogeography of the area and to evaluate rates of movement of existing small mammals across the Saddle. Further research will necessitate the granting of permits to collect plants and to trap small mammals in order to do more sophisticated genetic analysis.

Conclusion

Most evolutionists believe that if two populations are reasonably well isolated for long periods of time in nature, mutations and natural selection will take their course to produce microevolutionary changes which may lead to "allopatric speciation" and, ultimately, macroevolution. Anthony originally viewed Shiva Temple as having been completely isolated for a long period of time. Therefore, at first, he fully expected to find significant differences between the mammals of the North Rim and Shiva Temple because the microevolutionary prerequisites of isolation and time had seemingly both been met. But, in the only existing study of these mammals, Anthony (1937) acknowledged that he could find no detectable differences to support his evolutionary assumptions. He therefore reversed his position and concluded that the isolation must surely have been lacking, otherwise microevolution and perhaps even speciation would have occurred.

In contrast, we present evidence consistent with a recent origin and significant isolation of Shiva Temple from the North Rim. The conclusions of our preliminary studies support the previously suggested existence of major climatic and vegetational differences between Shiva Saddle and the North Rim which would be a barrier to the migration of a number of small mammals. We have also shown from existing data that some mammals present on both Shiva Temple and the North Rim are probably absent from the Saddle. This is in direct opposition to Anthony's final conclusion which was unchallenged in the literature.

Thus, given the apparent geographic isolation of Shiva, we tentatively conclude that one of two views is likely to be true:

1. *If* microevolutionary changes may be expected to occur as a result of isolation *then* the isolation of Shiva Temple must have occurred very recently—so recently that no microevolutionary changes had time to occur. This is of considerable importance since most uniformitarians would assert that the large canyon separating Shiva from the North Rim was carved during the Pleistocene, up to 50,000 or perhaps 100,000 years ago—see Babbitt (1981) and Krutch (1958) for a popular discussion. In reality it appears that the isolation occurred so recently that there has been insufficient time for even microevolutionary change to have occurred. This adds strength to the argument that the Grand Canyon itself is also of rather recent origin.

2. But, *if* Shiva Temple has been isolated for considerable time, *then* it is an exceptional instance in which neither microevolution nor allopatric speciation has resulted. This conclusion would also appear to be inconsistent with a considerable segment of evolutionary theory.

Thus, it appears that data supporting isolation of Shiva Temple for some mammals provides evolutionary theory with a two-horned dilemma. On the one hand, short-term isolation of small mammals on Shiva Temple presents the problem of a recent formation of this topographical feature. On the other, long-term isolation of small mammals on Shiva Temple without concomitant changes in gene frequency is hardly consistent with allopatric speciation.

From our study of the literature on population genetics and the demonstrated changes of gene frequencies within isolated populations, we suspect that the first conclusion (recent isolation) is valid because there are numerous data supporting the belief that isolation for even relatively short periods of time may yield small, limited, but measurable degrees of biological change. Thus, we tentatively conclude that Anthony was wrong and that Shiva Temple became isolated from the North Rim only very recently.

Future Work

An approach of the type we have used here opens the possibility of indirectly evaluating the age of any geographic barrier by studying the small terrestrial animals whose ranges are dissected by that same barrier. If their separation occurred quite recently, as seems to have been the case at Shiva Temple, one would expect to find that the populations are quite similar.

Acknowledgements

This work in its entirety was supported by interest proceeds from the Creation Research Society Research Fund. The authors thank the generous contributors to that fund, without which this study would not have been possible.

We also thank Jim Owen and Ron Surls of the Christian Wilderness Association for their assistance in data collecting and equipment transport to the North Rim of the Grand Canyon and the Shiva Saddle area. We are grateful to Ross Marshall for handling the art work.

References

CRSQ—Creation Research Society Quarterly

Anthony, Harold E., 1937. The facts about Shiva—the real story of one of the most popular scientific adventures in recent years. *Natural History.* 40:708-21, 775-6.

Babbit, Bruce, editor. 1981. Grand Canyon, an anthology. Northland Press. Flagstaff. pp. 42-3.

Golike, S. and G. Howe. 1975. The Grand Canyon—a winter ecology laboratory. *Bible-Science Newsletter.* 13(2):1-3.

Hoffmeister, Donald F. 1971. Mammals of Grand Canyon. University of Chicago Press. Chicago.

Krutch, Joseph W. 1958 Grand Canyon—Today and all its yesterdays William Morrow and Company. New York. pp. 198-9.

Malm, William C. 1974. Air movement in the Grand Canyon. *Plateau* 46(4):125-32.

McKee, Edwin D. 1937. Regarding Shiva Temple expedition. Memorandum dated October 25 in Grand Canyon National Park Research Library.

Merkle, John. 1962. Plant communities of the Grand Canyon area, Arizona. *Ecology* 43:698-711.

Meyer, John R. 1985. Origin of the Kaibab Squirrel. *CRSQ* 22:68-78.

________1987. Shiva Temple, island in the sky? *CRSQ* 24:120-5.

Rasmussen, D. Irvin. 1941 Biotic communities of Kaibab Plateau, Arizona. *Ecological Monographs.* 11:229-275.

Stansfield, William D. 1977. The science of evolution. Macmillan. New York. pp. 413-6.

Williams, Emmett L. 1986. Kaibab and Abert squirrels. *CRSQ.* 22:182.

Appendix A

Comparative Biogeography of Plants of Shiva Temple/North Rim Area.

Plants observed on two hiking expeditions from the campground at North Rim to Shiva Expedition Point or Shiva Saddle, North Rim, Grand Canyon National Park, June 2-5, 1979, and July 1-4, 1985. Plants have been alphabetized by genus names.

The list is not exhaustive as we had only limited time to botanize, a small number of taxonomy books in our packs, and no permits to collect plants for subsequent study. Thus, identification was carried out in the field between periods of hiking and camping.

One or more numbers are listed after each plant, indicating where the particular species was found among the following regions:

I. North Rim campground and higher altitude trails. Complex forest of spruce, fir, aspen, and Ponderosa Pine. 8200 feet plus.
II. Sunken meadows along the upper trail. 8200 feet plus.
III. Ponderosa Pine forests of the lower trail down to and including Shiva Expedition Point. 7600-8200 feet.
IV. Exposed, rocky, south-facing cliffs at Shiva Exedition Point. 7600 feet.
V. Sheltered ravines sloping both eastward and westward from center of Shiva Expedition Point. 7600 feet.
VI. The trail from Shiva Expedition Point down to Shiva Saddle. 6300-7600 feet.
VII. Shiva Saddle itself. 6300 feet.

More exhaustive treatments of plant communities on the entire Kaibab Plateau are found in Rasmussen (1941) and Merkle (1962).

Abies concolor, white fir: I.
Achillea lanulosa, western yarrow: III.
Agave utahensis, Utah agave: IV, VI, VII.
Algae mats, dried with the soil: VII.
Amelanchier utahensis, Utah serviceberry: IV, VI, VII.
Aquilegia coerulea, white columbine: I.
Arctostaphylos sp., manzanita: VI, VII.
Artemesia sp., sagebrush: IV, VI, VII.
Asclepias subverticellata, poison milkweed: III, VII.
Aster sp., aster: III.
Berberis repens, Oregon grape: I, II.
Calochortus sp., mariposa lily: VII.
Castilleja sp., paint brush: I.
Ceanothus fendleri, buckbrush: I.
Cercocarpus ledifolius, curleaf mountain mahogany: IV, VI.
Cercocarpus sp., (a broad-leaved cercocarpus—not ledifolius): VI, VII.
Chamaebatiaria millifolium, fernbush: IV, VI.
Circium sp., thistle: III.
Cowania mexicana, cliffrose: III, IV, VI, VII.
Crypthantha sp., yellow borage: III.
Delphinium nelsoni, larkspur: III.
Draba asperella, golden whitlow: II, III.
Ephedra torreyana, ephedra or jointfir: IV, VI, VII.
Erigeron sp., daisy: II.
Fragaria sp., wild strawberry: I.
Fraxinus cuspidata var micropetala, flowering ash: V.
Fritillaria atropurpurea, chocolate lily or fritillary: III, V.
Galium boreale, bedstraw: IV.
Geaster, earthstar fungus: VI.
Geranium richardsonii, cranesbill: I
Gilia aggregata, skyrocket gilia: V.
Gutierrezia sarothrae, snakeweed: VI, VII.
Heuchera sp., alumroot: III.
Juniperus communis, common juniper: I, II.
J. monosperma, one-seeded juniper: IV, VI.
J. utahensis, Utah juniper: IV, VI, VII.
Lichens (small size, on ground): VII.
Lichens (large ones up to 23 cm diameter, on ground): III.
Linum Lewisii, blue flax: II.
Lithophragma tentellum, star Bethlehem: III.
Lomatium sp.: I, II.
Lotus wrightii, deervetch: I, III.
Lupinus palmeri, lupin: I, II, III.
Mammilaria arizonica, Arizona pincushion: III, IV, VI.
Mertensia sp., bluebells: I.
Moss pads, dried: VII.
Oenothera caespitosa, white tufted evening primrose: III.
Opuntia sp., prickly pear: VII.
Pedicularis centrantha, wood betony: III.
Penstemon palmeri, penstemon: VII.
P. sp., scarlet bugler: I.
P. virgatus, wandbloom penstemon: I, (?)VII.
Phacelia heterophpylla, caterpillar plant: I, III.
Phlox sp., phlox: I, IV, VI.
Picea engelmannii, Englemann spruce: I.
P. pungens, blue spruce: I.
Pinus edulis, pinyon pine: IV, VI, VII.
P. ponderosa, ponderosa or western yellow pine: I, III, IV, V.
Potentilla sp., cinquefoil: II.
Pteridium sp., bracken fern: I.
Pteospera andromedea, woodland pinedrops: III.
Quercus gambelii, Gambel oak: III, IV, V.
Q. turbinella, scrub live oak: IV, VI, VII.
Ranunculus sp., buttercup: II.
Rhus trilobata simplicifolia, Utah squawbush: VII.
Ribes sp., currant: III, IV, V.
Robinia neomexicana, New Mexico locust: III, V.
Sambucus sp., elderberry: III.
Smilacina racemosa, false Solomon's seal: IV.
Stipa sp., needlegrass: VII.
Swertia radiata green gentian: II.
Thallictrum sp., meadow rue: III.
Townsendia excapa, ground daisy: III.
Trifolium sp., clover: III.
Yucca baccata, banana yucca or datil: IV, VI, VII.

Appendix B

Comparative Biogeography of Mammals of Shiva Temple/North Rim Area.

The left-hand column displays the scientific and popular names of mammals of the area. The remainder of the columns identify the presence of each animal in specific areas based on the indicated sources.

The second and third columns identify animals known to be on Shiva Temple, based on the American Museum of Natural History (A.M.N.H.) species list from the 1937 Anthony expedition and Hoffmeister's work (1971). Columns four and five identify animals present on the Saddle based on the distribution indicated by Hoffmeister (1971) and the indication by Rasmussen (1941) of specific inhabitants of the *Pinus juniperus* community of which the Saddle is composed. The sixth and seventh columns identify animals present on the North Rim as indicated by Hoffmeister (1971) and Rasmussen (1941) for the *Pinus brachypterm* (Pinus brach.) which compose the area along the edge of the North Rim. Note, *Pinus brachypterus* is the scientific name for Ponderosa Pine.

Comparative Biogeography of the Shiva Temple Area

	Source Reference and Grand Canyon Location					
	Shiva Temple		Shiva Saddle Area		North Rim and Kaibab Plateau	
Scientific Name Popular Name	A.M.N.H. Shiva Temple	Hoffmeister Shiva Temple	Hoffmeister Saddle	Rasmussen Pinus-Juniperus	North Rim	Rasmussen Pinus-Brachypterus
Bassariscus astutus Ringtail Cat	----------	Present	Present	----------	----------	----------
Canis latrans Coyote	----------	Present	Present	Present	Present	Present
Citellus lateralis lateralis Ground Squirrel	----------	----------	----------	----------	----------	Present
Citellus variegatus utah Rock Squirrel	Present	Present	Present	Present	Present	Present
Erethizon dorsatum spixanthum Porcupine	----------	Present	----------	Present	Present	Present
Eutamias umbrinus Uinta Chipmunk	----------	----------	----------	----------	Present	Present
Eutamius dorsalis utahensis Cliff Chipmunk	Present	Present	----------	Present*	Present*	----------
Eutamias minimus consobrinus Wasatch Chipmumk	----------	----------	----------	----------	----------	Present
Neotoma lepida monstrabilis Desert Wood Rat	Present	----------	Present	Present	----------	----------
Neotoma cinerea Bushy-tailed Wood Rat	Present	Present	----------	----------	Present*	Present
Peromyscus boylii rowleyi Brush Mouse	Present	Present	Present*	----------	Present*	----------
Peromyscus crinitus Canyon Mouse	Present	Present	----------	----------	Present*	----------
Peromyscus eremicus Cactus Mouse	----------	----------	Present	----------		
Peromyscus maniculatus Deer Mouse	Present	Present	----------	Present	Present	Present
Peromyscus truei Pinon Mouse	Present	Present	----------	Present*	Present*	----------
Spirogale putorius (gracilis) Spotted Skunk	----------	Present	Present	Present	----------	----------
Sylvilagus nuttallii Nuttall's Cottontail	Present	Present	Probable	Present	Present	Present
Other Major Species of the Area Not Directly Related to the Present Study						
Sciurus kaibabensis Kaibab Squirrel	----------	----------	----------	----------	Present	Present
Lepus californicus Black-Tailed Jack Rabbit	----------	----------	----------	Present	Present	----------
Lynx rufus baileyi Bobcat	----------	Probable	Probable	Present	Present	Present
Odocoileus hemionus hemionus Mule Deer	----------	Present	Probable	Present	Present	Present
Urocyon cinereoargenteus Gray Fox	----------	Probable	Probable	Present	Present	----------

Note: Locations listed as "probable" are those for species indicated by Hoffmeister as being found throughout the Park or specifically indicated as probable for a given location.
* = Found primarily in the rim rock area along the edge of the Kaibab Plateau.