behavior cited by Tarr and Martin and then to search for other examples of this behavior which show a clear association, or lack thereof, with the 1964 earthquake.

Aerial investigations since 1960 in Alaska and Yukon, and earlier work on the rapid advances of the Muldrow, Black Rapids, and Susitna Glaciers (*7*), have led to the identification of a type of glacier behavior (here called surges) which can be clearly distinguished from normal, climatically induced advances. A typical surge occurs as follows:

After a relatively long interval (of the order of 15 to 100 years) of virtual stagnation in the terminal area, an abrupt kinematic wave from the upper glacier moves very rapidly downvalley. This results in a rapid transfer of ice from the upper regions toward the terminus, and the surface of the glacier is chaotically broken. A surface displacement of 4 km or more often takes place in a single year. The ice discharge may lower the surface of the ice as much as 60 m in the upper part of the glacier. This overrides or thrusts ahead the stagnant ice at the terminus. Only in exceptional cases does the glacier advance beyond its former limit. The active period of these surges generally does not appear to exceed 3 years, regardless of the size of the glacier. Such surges may occur repeatedly in a single glacier; distinctive medial-moraine patterns or surface textures frequently provide evidence of three or more former surges. Conterminous glaciers and even individual branches in a single large glacier may not surge at the same time. Surging glaciers are rare but have been reported in many parts of the world (*8*).

All features of the nine glacier advances described by Tarr and Martin are typical of surges as described above. Thus a special search was made in 1964 for new surges. Except for the Martin River tributary glacier mentioned earlier, only the Variegated, Butler, and Art Lewis Glaciers showed any evidence of starting surges in 1964. Photographs of them show no abnormal avalanching. These glaciers are all in the St. Elias Mountains, about 450 km from the earthquake epicenter, and on the limit of the area where earthquake shaking caused cracking in alluvial deposits (Fig. 3).

Surges of other glaciers which have been observed since 1960 include the following: Klutlan and Walsh Glaciers (St. Elias Mountains), surged between 1960 and 1963; Gakona Glacier (Alaska Range) and "Tika" Glacier (near the Fairweather Range) both started surges in 1963 and were chaotically broken and evidently moving rapidly in 1964.

All of my observations suggest that the 1964 earthquake induced little significant snow and ice avalanching. Five months after the earthquake I found only one glacier which had been subjected to abnormal avalanching and which also showed some evidence of the beginning of a surge.

Other evidence which casts doubt on the earthquake-advance theory includes (i) a lack of correlation in time and space between earthquakes and glacier surges since Tarr and Martin studies (Fig. 3), (ii) the fact that two of Tarr and Martin's nine glaciers head in open basins where appreciable avalanching is unlikely, and (iii) a breakdown of Tarr and Martin's correlation between glacier lengths and time delays since the earthquake, when these lengths are measured on modern, accurate maps.

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9. Many glacier surges have doubtless gone undetected since 1900 owing to the dearth of investigations between 1913 and 1960. The apparent concentration of surging glaciers in the early 1900's in the Yakutat Bay area shown in Fig. 3 is probably due at least in part to a concentration of investigations in that area at that time.
10. Investigations in 1960, 1961, and 1963 were sponsored by NSF grants to the University of Washington, Department of Atmospheric Sciences. The 1964 studies were sponsored by the U.S. Geological Survey. W. Fairchild, D. Sheldon, and J. Wilson provided skilled piloting on aerial photographic missions in difficult terrain. Publication authorized by the Director, U.S. Geological Survey.

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Split-Twig Figurines from Northern Arizona: New Radiocarbon Dates

Abstract. *Recently released radiocarbon dates for split-twig figurines from Marble Canyon, Arizona, are 4095 ± 100 years ago; they substantiate previously determined dates of 3530 ± 300 and 3100 ± 110 years ago. A recently excavated site in Walnut Canyon, Arizona, extends the geographical range of the figurines. The dates of samples from this site are 3500 ± 100 and 3880 ± 90 years ago. It is hypothesized that the figurines were magicoreligious artifacts related to the Pinto complex of the Desert Culture.*

In 1958 a detailed study was published (*1*) of the "Grand Canyon Figurine Complex," represented by distinctive and well-constructed animal effigies made of split willow (*Salix* sp.) twigs (see Fig. 1). In that paper the first radiocarbon dating of these artifacts, and dates of 3100 ± 110 and 3530 ± 300 years ago, were reported. Eleven discoveries from at least nine separate sites in the Grand Canyon and adjacent areas of northern Arizona and southeastern Nevada were described. It was postulated that, although "no material was found associated with the split-twig figurines which would allow for definite placement with any established archaeological complex in the Southwest or the Basin," they were magicoreligious objects that "may have been part of the widespread Desert Culture."

In the summer and fall of 1963, two new collections of split-twig figurines were made in northern Arizona by Euler and Olson. Euler, in a visit to Stantons' Cave, the site at which some of the first-reported of these enigmatic artifacts were found, recovered ten complete and ten fragmentary specimens. This site (Ariz. C:5:3 in the Arizona State College Archaeological Survey) is on the Colorado River at an elevation of 2785 feet (847 m); it is in the inner gorge of Marble Canyon and is approximately 50 km upstream from the boundary of Grand Canyon National Park. The huge limestone solution cavern contained no surface evidence of human occupation except the figurines, which were found in three separate caches near the entrance, under large rockfalls from the ceiling of the cave. The artifacts conformed in every respect to those previously reported, ranging in length from 7.5 to 19.0 cm. Seven of them were pierced through the body by unsplit twigs 8.9 and 31.0

cm long. One fragmentary figurine (UCLA-741) was dated by the Radiocarbon Laboratory of the University of California, Los Angeles, at 4095 ± 100 years ago.

The second of the new collections is from site NA 5606, a small limestone rock-shelter in the north wall of Walnut Canyon, a short distance from the western boundary of Walnut Canyon National Monument. The site was excavated by the Museum of Northern Arizona. The ceiling of the overhang is very low, and most of the occupational evidence was found near the mouth. The figurines, however, were scattered throughout the less accessible portions of the shelter. Stratigraphic excavation was rendered difficult or impossible by the extreme shallowness (10 to 15 cm) of the deposit in most parts of the cave; at the entrance a small section of the deposit was nearly 50 cm deep, but no figurines or fragments came from this area.

Eight complete specimens and 23 fragments were found. The complete artifacts ranged in length from 2.5 to 10.0 cm, and none was pierced by the symbolic twig spear. In material and construction technique these specimens were similar to the figurines described by Schwartz *et al.* (*1*), as well as to those found in Stanton's Cave.

Associated with the figurines were various nondiagnostic yucca fibers, knots, and "needles" made from yucca leaves by retaining the sharp point and twisting the attached fibers into a thread. A number of willow twigs, split and unsplit, were found; none of these seemed to have been used. An antler punch and three large projectile points or knives, one retaining a stain of gum used for hafting, were found; all are nondiagnostic. Of the few sherds found, the majority were from the Cohonina culture area to the northwest of Flagstaff; a single sherd indicated a Kayenta cultural source. None of the sherds was decorated, nor could any of them be assigned a more accurate time range than the period from the 10th to the 13th centuries A.D. These sherds suggest a very sporadic occupation of the cave long after the deposition of the figurines.

Two samples of the figurine fragments were dated by the radiocarbon method. One sample (SI-86) was dated by the Smithsonian Institution at 3880 ± 90 years ago; the other (UCLA-741B) was dated by the Radiocarbon Laboratory of the University of California, Los Angeles, at 3500 ± 100 years ago.

Fig. 1. Animal effigy made of split willow twig. Actual length, 12.5 cm.

We had suspected that the specimens originally subjected to radiocarbon dating might have been contaminated by carbonates from their contexts in limestone caves. However, both the Smithsonian and the University of California laboratories subjected the samples, prior to dating, to a rinse of dilute hydrochloric acid to remove any such impurity. The newly obtained dates generally confirm the earlier determinations, and the earliest known utilization of Grand Canyon and Walnut Canyon by human beings thus seems to have been between 3000 and 4000 years ago, some 2000 years earlier than any other known habitation in that region.

To date, no split-twig figurines have been found in indisputable association with other diagnostic cultural remains. The earlier hypothesis that these figurines were a Desert Culture manifestation was based on their antiquity. Certainly the figurines are not common in known Desert Culture sites (*2*). Yet, their range is within that of the Desert Culture complex (*1*, *2*), and magico-religious aspects of hunting seem to have been present in that complex during the time the figurines were manufactured (*3*). Recently, the first evidence of a Pinto Complex occupation near Grand Canyon was recorded by Euler. This was a Desert Culture component marked by stemmed projectile points with indented bases; it seems to fall within the demonstrable time range of the figurines (*4*), although some workers are as yet unwilling to accept such an early date (*2*). However, if the Pinto Complex does have a range of 3000 to 4000 years ago, given the proximity of a Pinto site to most of the figurine locations, it may be postulated that Pinto hunters were responsible for the manufacture of the figurines in the Grand Canyon.

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