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Projectile-Impact Structures (A New Type of Sedimentary Structure)

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ABSTRACT

Projectile-impact structures were formed in the eroded blanket of soft mud deposited as bottom-set beds in a fan delta developed in a flood-control reservoir in Provo, Utah, during the flooding of 1983.

The reservoir was drained because of leakage in the face of the dam, and floodwaters quickly eroded down through the fan delta and carved steep-walled channels in the soft bottom-set muds. The floodwaters ejected cobbles into the vertical banks of the stream channels, and the stones remained imbedded in the soft mud.

This is a new type of sedimentary structure, and this study of how these structures were formed under very restricted conditions suggests why they have not been reported before.

INTRODUCTION

Projectile-impact structures were discovered in a flood-control reservoir located in the northeast part of Provo at the mouth of Rock Canyon. Provo is 45 miles south of Salt Lake City, Utah.

The flood-control reservoir was filled to capacity during the flood of 1983 (maximum depth 5 m). After a few weeks the reservoir was drained because of leakage in the dam face. The removal of the water revealed a fan delta that had built out into the reservoir. Ahead of the fan-delta front was a dark brown blanket, up to a meter and a half thick, of fine-grained, bottom-set muds. A remarkable aspect of the contact of the fan-delta front and the bottom-set beds was the abrupt 30° angle of contact. The fan-delta front was up to 2 m high and consisted primarily of gravel, from pebble-size gravel to gravel 15 cm in diameter, and light gray in color (fig. 1A). There was no significant evidence of a gradation in grain size between the gravels of the fan-delta front and the fine-grained, bottom-set beds.

The floodwaters that continued to flow into the flood-control reservoir after it was drained cut down through the fan-delta front and quickly eroded meandering channels into the blanket of soft mud.

Nicholas Jones of the Provo City Engineering Office indicated to me personally that the floodwater flow reached a maximum of 200 cubic feet per second and over a period of 12 days fluctuated between 100 to 150 feet per second.

The sediments deposited in the flood-control reservoir were transported just a few hundred meters from where they were eroded from the upper part of the Rock Canyon alluvial fan. A significant aspect of the upper alluvial fan was that the unconsolidated sediments consisted primarily of coarse gravel and fine silt and clay with a very limited amount of intermediate grain sizes present.

DISCUSSION

There were three localities where projectile-impact structures were developed. Ten or more projectile-impact structures were found at each site, produced by cobbles up to 12 cm in diameter. Each locality was located at a sharp bend in the stream channel. Figure 1B shows one of these localities.

Close examination of the impact structures (fig. 1C) shows that the penetration of the cobbles into the mud produced slide surfaces that cut across the laminations in the mud and clearly show the angle of penetration of the cobbles into the mud. The direction of movement of the cobbles appears to have been the same as the direction of flow of the stream prior to the change of direction of the stream to follow an abrupt change in the direction of the channel.

The formation of a projectile-impact structure can be easily demonstrated by dropping a cobble into semifirm mud. The penetration of the cobble produces glide surfaces in the mud that reflect the angle of penetration and also the slope of the surface penetrated (fig. 1D).

The present classification of sedimentary structures does not include a specific group of what might be called impact structures. However, isolated references in the literature describe a few structures that have similarities to projectile-impact structures. Raindrop impressions, drop stones, and volcanic bomb impacts into volcanic ash have similar modes of origin and appearance.

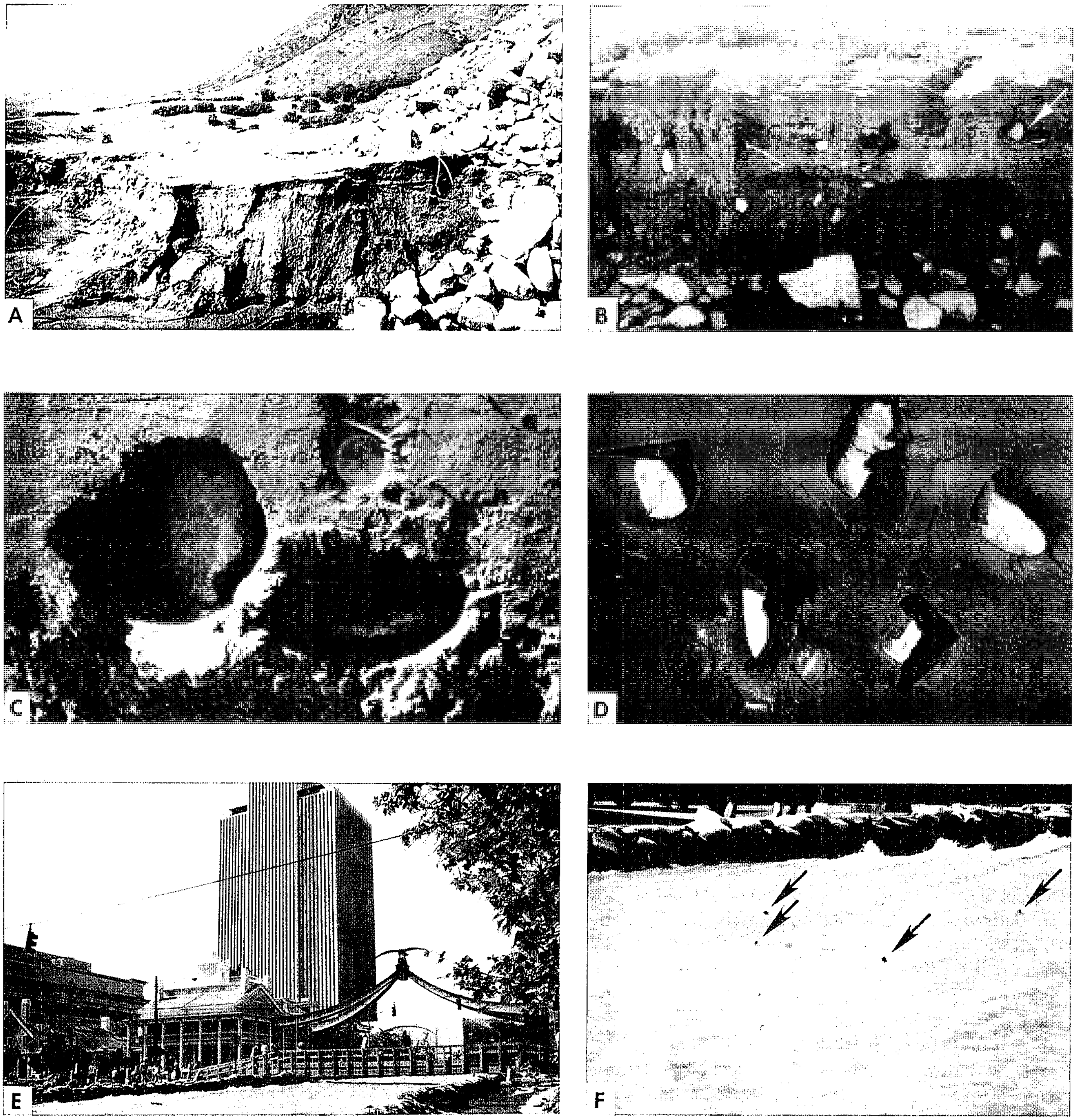

FIGURE 1.—*(A) Flood-control reservoir deposits; fan-delta gravel front and bottom-set muds. (B) Projectile-impact structures emplaced in channel bank of eroded bottom-set muds. (C) Close-up (see arrow in B) of projectile-impact structures. (D) Note penetration slide surfaces associated with cobbles dropped in mud. (E) Floodwater flowing down State Street, Salt Lake City. (F) Cobbles ejected into the air from the floodwater.*

Excavation by hand shovel immediately behind the face where the projectile-impact structures were located produced no additional stones.

As the blanket of fine-grained mud (which covered several thousand square meters) was completely removed for use as topsoil, a close check was made of the composition and character of the mud and also for the presence of additional cobbles in the sediments. No more stones were found, and the blanket of mud was shown to be exceptionally uniform in texture and bedding.

The problem to solve was, how do you test the movement of cobbles in a stream to see if they can develop enough energy of movement to become projectiles?

Salt Lake City, as well as Provo, suffered from the effects of flooding in 1983. Figure 1E shows the floodwaters from City Creek Canyon being diverted down State Street. Chuck Hall of the Salt Lake City Engineering Office told me that the floodwater flow out of City Creek Canyon averaged 190 cubic feet per second over a 10-day period.

The gradient of State Street changes from 1.65% to horizontal at South Temple Street and then to 4.07% on State Street south of South Temple Street. (Gradient information also given to me by Chuck Hall.)

At the point where the flow of the water changed from the horizontal level of South Temple to the steeper gradient to the south on State Street, cobbles up to fist-size were seen being ejected from the water into the air (fig. 1E, 1F). In some cases the trajectory of the cobbles in the air before falling back into the water was more than a meter in length. During an interval of about 15 minutes, I personally saw about a dozen cobbles being ejected into the air.

CONCLUSIONS AND COMMENTS

The observation of cobbles being moved by floodwaters and actually being ejected from the water into airborne trajectories clearly shows a means by which the projectile-impact structures in the soft mud of the Rock Canyon flood-control reservoir sediments could have been formed.

These impact structures have a very limiting set of circumstances in which they can form and be preserved. The location of the structures must remain above the level of the streams or not be exposed for any significant amount of time to stream erosion or they would be destroyed. In addition, the steep erosion channel banks could be rapidly undercut and the evidence of projectile impact structures eliminated.

Roger W. Walker, in the preface to "Sedimentology of Gravels and Conglomerates," Memoir 10 of the Canadian Society of Petroleum Geologists (1984), indicates that the study of gravels and conglomerates is severely hampered by the lack of experimental work done in the laboratory. This is primarily because of the difficulty in the laboratory of devising workable methods to study the transportation and deposition of gravels.

This study about projectile-impact structures adds useful information about the transportation movement of gravels and should encourage additional research. Another comment by Roger W. Walker is appropriate in respect to field studies such as this one. "I feel, therefore, that the sharp-eyed geologist still has a lot to contribute to the understanding of gravels and conglomerates, even if the results are ambiguous."

REFERENCES CITED

Walker, R. W., 1984, Sedimentology of gravels and conglomerates: Canadian Society of Petroleum Geologists Memoir 10, Preface, ix–x.