

HYDROLOGIE

MÉLANGES

OFFERTS PAR SES AMIS ET DISCIPLES

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MAURICE PARDÉ

*Professeur Honoraire de Potamologie
à l'Université de Grenoble*



EXTRAIT

Editions. OPHRYS

SOME OBSERVATIONS ON THE COLORADO RIVER IN THE GRAND CANYON, U.S.A.

par Luna B. LEOPOLD
U.S. Geological Survey, Washington

Before us the river roars darkly. Beneath us is soft white sand curling narrowly around the nose of a red cliff. In front of us, across the turbulent water, we look into a face so sheer, so imposing, and so deeply orange in color that it is as if the sun itself were our front yard as well as our horizon.

Downstream to our left the ribbon of white water disappears in a purple notch. Upstream the curve of the canyon is such that the sun shines directly on the water and blinds me with gold.

It is morning in the Grand Canyon. Yesterday we rode one massive rapids after another. The map tells us that in the days ahead there will be still bigger ones : the Unkar Gorge, Hance Rapids, and Grapevine Canyon. The rubber pontoons which serve as boats are tugging at the ropes ready to begin the day's journey, but at each new start I feel again the fear in my stomach and a lump in my throat.

About a hundred years ago John Wesley Powell camped on this same sand bar and looked across the river at the thousand-foot cliff washed in morning sunlight. On that hazardous first exploration of the Canyon he did not have the protection of a flexible rubber boat and each one of the rapids was a new trial of courage and strength. His little wooden skiffs had to be lined or roped from rock to rock down through the dashing water.

Even though running the rapids of great rivers is today relatively but not completely safe, it is still a wilderness experience. Any such experience which allows a man to relive some part of the history of his progenitors is educational. In his exploration down the Grand Canyon the fear that lurked in the back of Powell's mind was that there might be a waterfall not only unknown but unseen which would in a moment carry him to disaster. At least we were spared this worry.

One of most amazing things about the Powell expedition is that, despite the hazards and the exertion, he was very observant of the landscape. The notes he took in the field were probably not extensive, though his sketch maps and barometric observations were apparently

kept with great care. Yet on his return Powell wrote an account of the trip which was replete with detail. For pure geographic description I consider Powell's report surpassed only by T. E. Lawrence's *Seven Pillars of Wisdom*.

Up to the time of our expedition no detailed measurements had ever been made of the river depths through long reaches of a great canyon. Even the most experienced river men could not guess how deep were the great whirlpools below the big rapids of the Grand Canyon, where the surface boils caused by rising water could have a diameter of 10 meters or more.

Our trip down the Grand Canyon in June 1965, included a segment of the San Juan River and extended for about 550 kilometers and took 17 days by boat. In the Colorado canyon itself the discharge during this trip averaged 1,360 cubic meters per second, the mean water depth, 15 meters, mean width of water surface, 60 meters, and water surface slope varied from .0002 to .02, the former being characteristic of pools and the latter of the steepest rapids. The rapids are variable in length from 30 meters to .8 kilometers. For example, Badger Creek Rapids extends .16 kilometers at a slope of .016. Depths through the rapids vary from 5 to 8 meters and the mean water velocity probably is close to 5 meters per second.

Depth measurements were taken by a non-recording sonic sounder powered by battery. The depth record, read from a visual indicator, was recorded directly on an aerial photograph at the place where the observation was made. Throughout the several hundred kilometers traversed depth measurements were recorded on the average every 150 meters. The depth record is complete except for very turbulent water at the foot of rapids where the sonic sounder showed either violently fluctuating values of depth or no readings were obtainable. The exact reason for this interruption is unknown, but we surmised that air bubbles under the transducer due to the violent turbulence of the water interrupted the energy transmission.

Powell conjectured that the principal cause of the rapids in the Grand Canyon was debris fans choking the canyon at the mouths of side tributaries. Though important, in my view the rapids are caused also by other factors, including outcrops of especially resistant rock, narrowing of the gorge by hard rock, and rock-falls from cliffs.

It was my observation that there generally occurred a long and deep hole or trough in the zone immediately downstream from most of the big rapids. After traversing the most violent section of the rapids we generally entered a length of water where there were no waves but there were large and powerful boils of upwelling water and swirling vortices of downward moving water. Wherever these large boils occurred the depth of the channel was very great, 25 to 30 meters being not uncommon. The maximum water depth recorded in the Grand Canyon was 33.5 meters.

Both from visual observation and from measurement the downstream velocity near the stream bed was extremely high in these deep reaches. At one place we measured a surface velocity of $3\frac{1}{2}$ meters

per second and exactly the same value when the current-meter weight was resting on the bottom.

On several occasions I put into the water immediately below a rapids a buoyant cloth sack containing dye. On nearly every occasion this object, which should have floated, immediately disappeared from sight and was next noted hundreds of meters downstream at the surface, appearing there in a remarkably short time. I would judge, then, that water at the foot of a steep rapids dives downward and runs near the bed as a high velocity filament gradually mixing and appearing at the surface several hundred meters downstream. This diving of surface water is accompanied by large-scale turbulent exchange between the surface and depth and is marked by upwelling boils and by vortices centered around downward moving filaments.

I have classified in a general way the rapids of the Grand Canyon in four categories representing four different causes for large or violent waves at the water surface.

Waves caused by large rocks at or near the surface.

These were often characterized by a standing wave of smooth fast water representing a topographic hump on the water surface and followed immediately downstream by a deep trough and a wave which curled back upstream into the trough.

Waves in deep water due to horizontal convergence.

Narrowing of the channel, tending to funnel all the flow into a constriction, characteristically causes a series of standing waves in the reach downstream.

Waves or ripples in shallow water.

These give a constant churning at the surface but do not often define identifiable standing waves of constant wave length.

Waves in high velocity water having considerable depth and related to high Froude Number.

The waves of these four categories are diagrammed in the accompanying figure 1.

In the United States and eventually in other parts of the world engineering plans for the construction of flood control or power reservoirs will progressively drown some of the most beautiful and interesting river gorges. Even now two power dams are contemplated in the Grand Canyon of the Colorado River, but a legion of conservationists vigorously oppose their construction. The unique beauty of the Grand Canyon, famous throughout the world, is conceived by

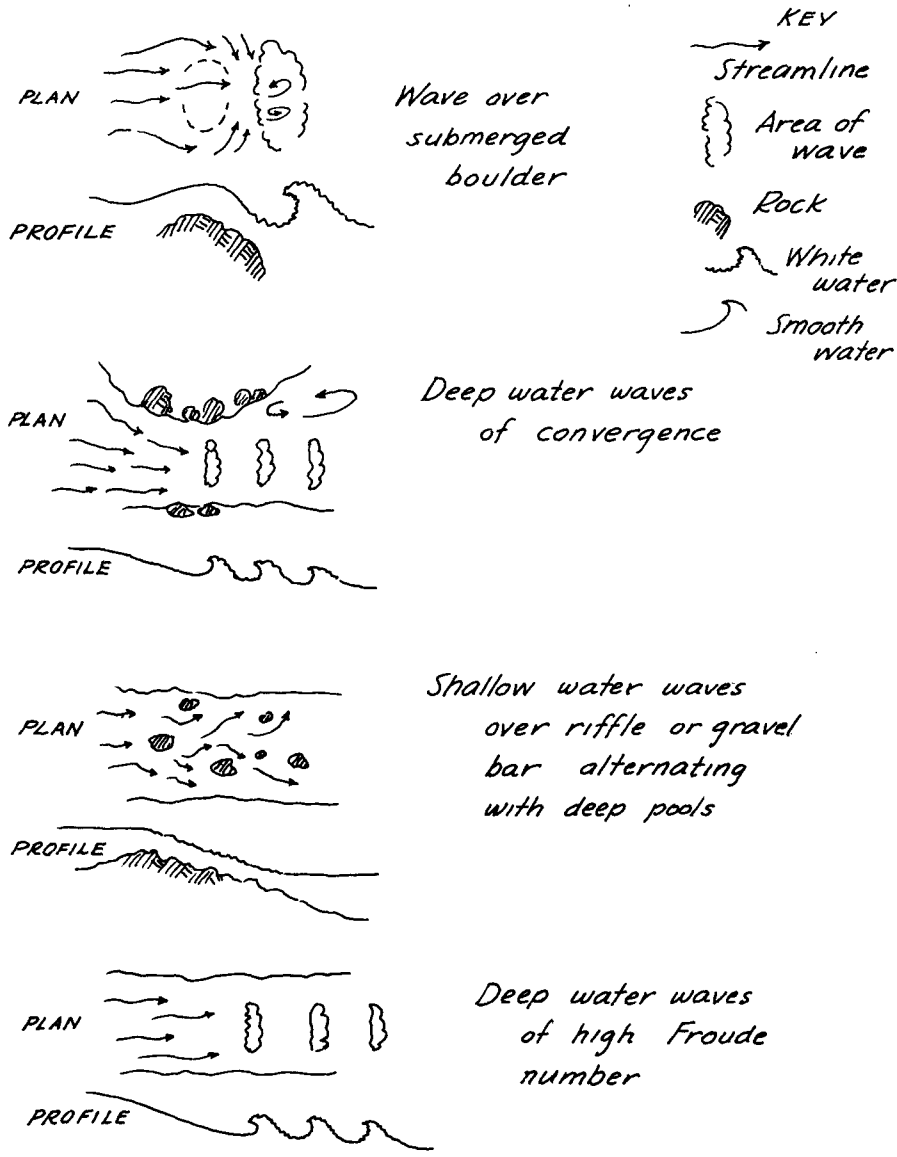


FIG. 1

many of us to have a greater value to man for its scenic beauty and its natural grandeur than for its use for the generation of electric power. In addition to unique beauty, wild canyons have only begun to be investigated from the scientific standpoint. There should be preserved some wild rivers in their native state. I hope that my grandchildren might know how darkly roars a great river.