Part XV

Submarine Canyons

The Channelized Flow Phase of the Flood was predominantly a linear erosive phase. So after the continental margins were deposited all around the continents after continental sheet erosion, the Channelized Flow Phase eroded the freshly deposited continental shelf and slope deposits. This was the time when linear cuts were made in the margin sediments, but now mostly consolidated to sedimentary rocks, resulting in deep submarine canyons, which are difficult to explain by uniformitarianism.

Chapter 70

Submarine Canyons—Offshore "Grand Canyons"

The Channelized Flow Phase of the Flood carved linear channels, canyons, and pediments on the continents. Its work was not confined to the land, however; it continued offshore, cutting submarine canyons into the freshly-deposited continental shelf and slope sediments, but I am getting ahead of myself.

"Grand Canyons" Perpendicular to the Continental Margin

Many people have been to the rim of Grand Canyon. Gazing into the canyon, they are often in awe of its great depth and size, its multiple tributaries, and the beauty of its flat, colorful sedimentary layers. Surprisingly, there are a number of canyons of similar size and even larger, but they are usually unseen since they lie underwater. These are submarine canyons that run perpendicular to the coast and sometimes start close to shore. Submarine canyons are considered "…among the most dramatic geomorphic features on Earth…"[1]

Submarine canyons differ from deep-sea trenches, like the Mariana Trench, the deepest place in the oceans. Trenches generally run *parallel* to the shoreline or parallel to an island arc (a string of islands) and are located in deep water. They are fault-controlled structures, caused by downwarping of the ocean crust.[2] Submarine canyons, in contrast, start shallow and carve into deep water by *erosion* that is generally perpendicular to the sedimentary and igneous rocks of the continental margin.

Submarine Canyons Common

Submarine canyons are common across continental margins and island arcs,[3,4,5,6] as well as off large islands, like the Hawaiian Islands and western Corsica.[7] They are often but not always found seaward of major rivers, like the Congo and Hudson Rivers. An example is the submarine canyon that begins near the mouth of the Danube River.[8] The south coast of Australia is riddled with submarine canyons, resulting in a vertical relief up to 4,800 feet (1,465 m) on the

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[1] Paull, C.K., Caress, D.W., Lundsten, E., Gwiazda, R., Anderson, K., McGann, M., Conrad, J., Edwards, B. and Sumner, E.J., 2013. Anatomy of the la Jolla Submarine Canyon system; offshore southern California. *Marine Geology* 335:16–34.
[2] Oard, M.J., 2000. Subduction unlikely—Plate tectonics improbable. In, Reed, J.K. (editor), *Plate Tectonics: A Different View*, Creation Research Society Monograph No. 10, Creation Research Society, Chino Valley, AZ, pp. 93-145.
[3] Austin, S.A., 1983. Did landscapes evolve? *Acts and Facts Impact No 118*, Institute for Creation Research, Dallas, TX.
[4] Pickering, K.T., R.N. Hiscott, and F.J. Hein, 1989. *Deep-Marine Environments*, Unwin Hyman, London, U.K., pp. 133-159.
[5] Hagen, R.A., H. Vergara, and D.F. Naar, 1996. Morphology of San Antonio submarine canyon on the central Chile forearc. *Marine Geology* 129:197-205.
[6] Mullenbach, B.L., C.A. Nittrouer, P. Puig, and D.L. Orange, 2004. Sediment deposition in a modern submarine canyon: Eel Canyon, Northern California. *Marine Geology* 211:101-119.
[7] Kenyon, N.H., I. Klaucke, J. Millington, and M.K. Ivanov, 2002. Sand submarine canyon-mouth lobes on the western margin of Corsica and Sardinia, Mediterranean Sea. *Marine Geology* 184:69-84.
[8] Popescu, I., G. Lericolais, N. Panin, A. Normand, C. Dinu, and E. Le Drezen, 2004. The Danube submarine canyon (Black Sea): morphology and sedimentary processes. *Marine Geology* 206:249-265.

continental shelf and slope.[9] Peter Harris and Tanya Whiteway report that there are 5,849 submarine canyons greater than 330 feet (100 m) deep and spaced an average of 20 miles (33 km) apart.[10]

Submarine canyons have occasionally been carved through what are called forearcs, the accumulated sediments supposedly plastered onto the slope of a continent or island arc by plate convergence. Forearcs are composed of sedimentary rocks from the continent or island arc. Examples are found off the Izu-Bonin island arc southeast of Japan,[11,12] Chile,[13,14] and southern Taiwan.[15] Since the canyons intersect the forearcs, the forearcs developed *before* the submarine canyons were formed. Therefore, submarine canyons are a very late geological feature.

Two Types of Submarine Canyons

There are a variety of submarine canyons and include a few caused by faults.[16] There are two main types with the first and vast majority being slope canyons, confined only to the steep continental slope (Figure 70.1). Their canyon heads (where they begin) commonly start over 700 feet (215 m) deep.[17] These types of canyons never incised the continental shelf, since the boundary between the shelf and the slope is in about 425 feet (130 m) of water.[18] This first type is also shallow and straight.[19,20]

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[9] Von Der Borch, C.C., 1968. Southern Australian submarine canyons: their distribution and ages. *Marine Geology* 6:267-279.

[10] Harris, P.T. and T. Whiteway, 2011. Global distribution of large submarine canyons: geomorphic differences between active and passive continental margins. *Marine Geology* 285:69–86.

[11] Taylor, B. and N.C. Smoot, 1984. Morphology of Bonin fore-arc submarine canyons. *Geology* 12:724-727.

[12] Klaus, A. and B. Taylor, 1991. Submarine canyon development in the Izu-Bonin forearc: a SeaMARC II and seismic survey of Aoga Shima Canyon. *Marine Geophysical Researches* 13:131-152.

[13] Hagen, R.A., D.D. Begersen, R. Moberly, and W.T. Coulbourn, 1994. Morphology of a large meandering submarine canyon system on the Peru-Chile forearc. *Marine Geology* 119:7-38.

[14] Hagen, R.A., H. Vergara, and D.F. Naar, 1996. Morphology of San Antonio submarine canyon on the central Chile forearc. *Marine Geology* 129:197-205.

[15] Liu, C.-S., N. Lundberg, D.L. Reed, and Y.-L. Huang, 1993. Morphological and seismic characteristics of the Kaoping Submarine Canyon. *Marine Geology* 111:93-108.

[16] Lastras, G. et al., 2011. Understanding sediment dynamics of two large submarine valleys from seafloor data: Blanes andLa Fonera canyons, northwestern Mediterranean Sea. *Marine Geology* 280:21.

[17] Harris and Whiteway, Ref. 10, p. 76.

[18] Popescu *et al*., Ref. 8, pp. 249-250.

[19] Pratson, L.F., W.B.F. Ryan, G S. Mountain, and D.C. Twichell, 1994. Submarine canyon initiation by downslope-eroding sediment flows: evidence in late Cenozoic strata on the New Jersey continental slope. *GSA Bulletin* 106:395-412.

[20] Pratson, L.F. and B.J. Coakley, 1996. A model for the headward erosion of submarine canyons induced by downslope-eroding sediment flows. *GSA Bulletin* 108:225-234.

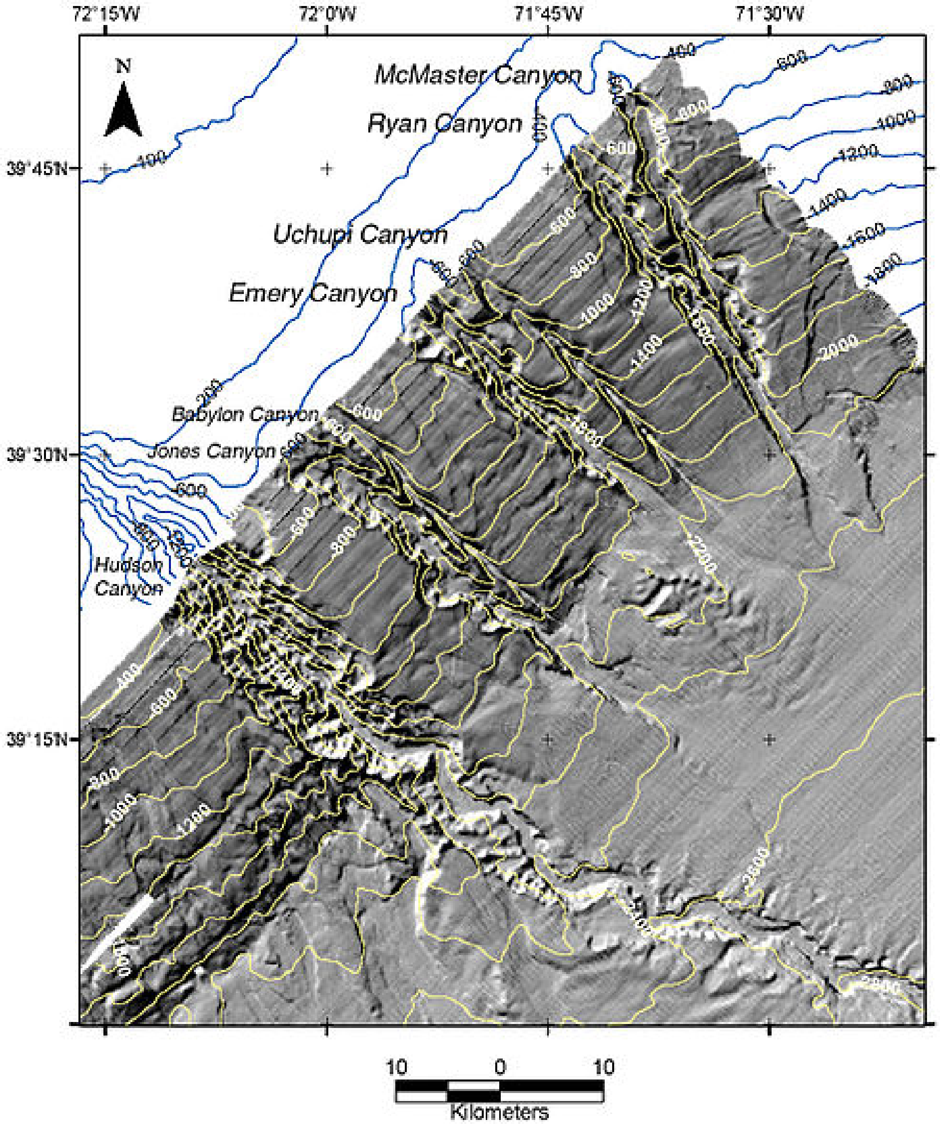

Figure 70.1. Shaded relief map of seven submarine canyons off New York (Wikipedia). Notice that six of them start on the edge of the continental shelf, but one, Hudson Canyon, traverses the continental slope.

Figure 70.2. The Congo Submarine Canyon off southwest Africa that starts at the Congo River and passes 187 miles (300 km) through the continental shelf (Wikipedia).

A second type of submarine canyon, much more significant, is those canyons that cut into the continental shelf sedimentary rocks (Figure 70.2). These types will be the main focus of Part XV. Shepard and Dill compiled a lifetime of research on submarine canyons that consisted of incomplete statistics on 93 submarine canyons.[21] The statistics were biased toward the better known canyons on the west coast of the United States and Baja California. The subsequent discovery of many more submarine canyons and fan valleys, extensions of the canyons out onto the submarine fan sediments, require Shepard and Dill's statistics be adjusted accordingly. Submarine fans are deposits that were transported from the canyon mouth onto the continental rise and abyssal plain. Most submarine canyons continue on top of the submarine fans as valleys but become shallower seaward. Nevertheless, Shepard and Dill's data does provide a general idea of the properties of submarine canyons, and I will refer to them often.

Amazing Chasms

If all of the ocean water were drained, submarine canyons would look like deep chasms, or multiple "Grand Canyons," that cut through the continental margin to the deep ocean basins. Over the years, oceanographers and marine geologists have collected a huge amount of data on these amazing canyons.

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[21] Shepard, F.P. and R.F. Dill, 1966. *Submarine Canyons and Other Sea Valleys*, Rand McNally & Company, Chicago, IL, pp. 223-231.

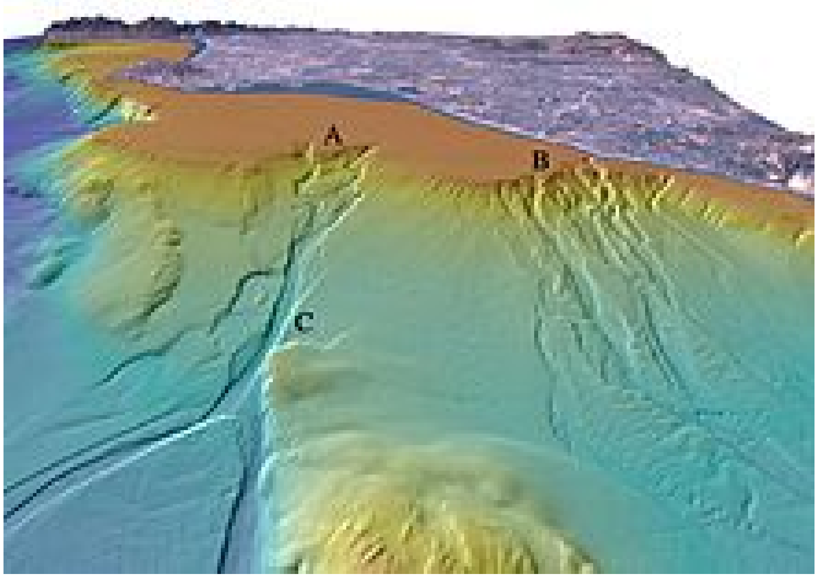

Figure 70.3. Shaded relief map of the San Gabriel and Newport submarine canyons off Los Angeles that indent the edge of the continental shelf (Wikipedia). Also note some type one slope canyons.

Sometimes Start in Shallow Water

The Submarine canyons begin at a water depths ranging from a few feet (about a meter) to more than 1,000 feet (300 m). The average is 350 feet (107 m), near the edge of the continental slope (Figure 70.3). The large Capbreton Canyon off northern Spain begins only 820 feet (250 m) from the shore at a water depth of only 100 feet (30 m)![22] The Scripps and La Jolla Canyons off La Jolla, California also start very close to the beach, so close in fact that Scripps Institute of Oceanography's pier would collapse into the canyon if it grew shoreward. The southern head of Monterey Canyon starts off the pier at Moss Landing in 60 feet (18 m) of water.[23]

The Length

The average length of a submarine canyon is 30 miles (50 km). This figure includes very short canyons off the Hawaiian Islands that are less than 10 miles (16 km) long and the longer canyons along the Bering Sea slope. The longest is the Bering Canyon, whose total length of 310 miles (495 km) and includes a 60 mile (95 km) long fan valley (Figure 70.4). This canyon is longer than Grand Canyon.[24,25] As I mentioned before, if the fan valleys were included in all of these statistics, the average would be much more than 30 miles (50 km). The Congo Canyon (Figure 70.1), for example, would change from 120 miles (190 km) to 500 miles (800 km).

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[22] Mulder, T. *et al.*, 2004. Understanding continent-ocean sediment transfer. *EOS, Transactions, American Geophysical Union* 85 (27):257, 261-262.
[23] Shepard and Dill, Ref. 21, p. 81.
[24] Carlson, P.R. and H.A. Karl, 1984. Discovery of two new large submarine canyons in the Bering Sea. *Marine Geology* 56:159-179.
[25] Karl, H.A., P.R. Carlson, and J.V. Gardner, 1996. Aleutian basin of the Bering Sea: styles of sedimentation and canyon development. In, Gardner, J.V., M.E. Field, and D.C. Twichell (editors), *Geology of the United States' Seafloor—The View from GLORIA*, Cambridge University Press, New York, NY, p. 305-332.

A few canyons actually begin on land. The submarine canyons off the west coast of Corsica in the Mediterranean Sea start on land, pass through the bays, and extend onto the continental slope.[7] The Zaire Canyon continues up the Zaire River for 19 miles (30 km).[26]

The terminal depth of most submarine canyons was poorly known when Sheppard and Dill completed their survey.[27] For those that are well surveyed, the average depth of termination is in about 6,000 feet (1,825 m) of water.

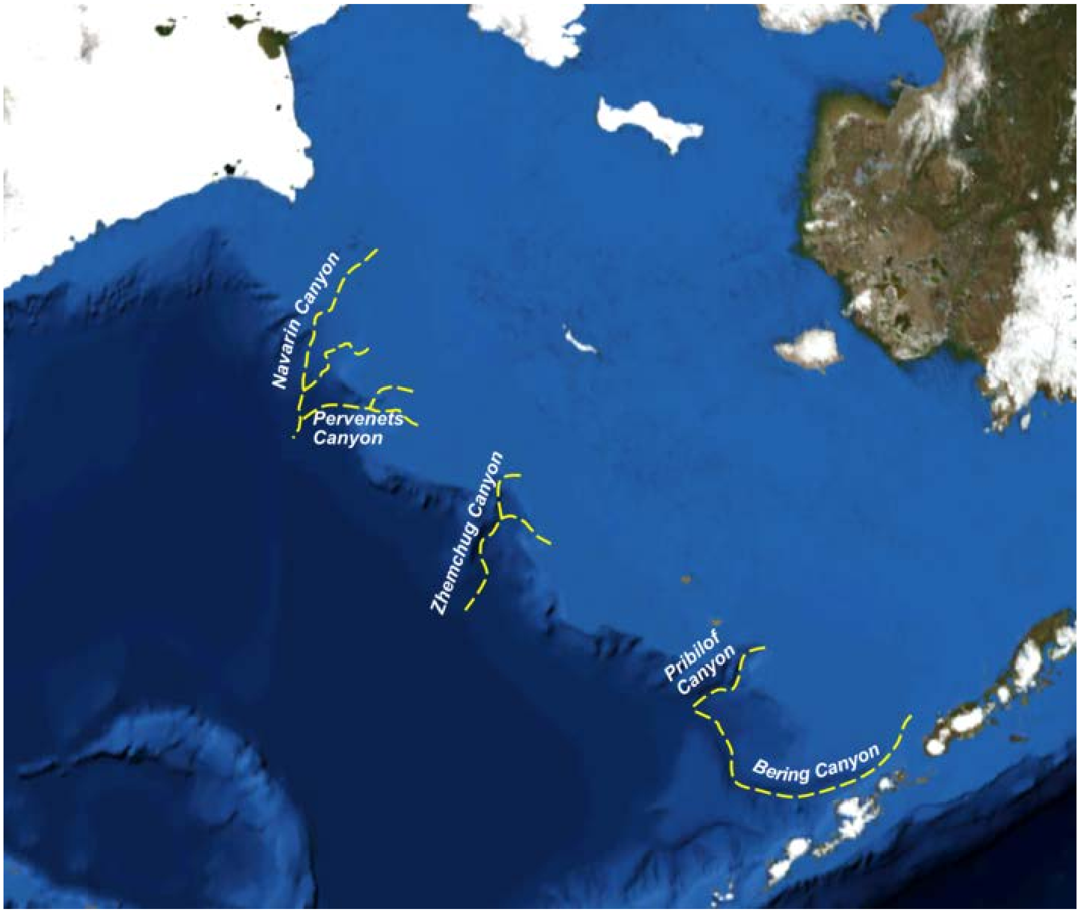

Figure 70.4. Large submarine canyons along the edge of the large Bering Sea continental shelf showing the location of the Bering Submarine Canyon, the longest on record (Wikipedia).

The Depth of the Canyon Walls

The depths of submarine canyons have attracted a great deal of attention, since some are deeper than the Grand Canyon. Figure 70.5 compares the cross-sectional area of various submarine canyons at the edge of the continental shelf with a profile across Grand Canyon.[28] Several of these canyons are significantly deeper and wider than Grand Canyon.

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[26] Babonneau, N., B. Savoye, M. Cremer, and B. Klein, 2002. Morphology and architecture of the present canyon and channel system of the Zaire deep-sea fan. *Marine and Petroleum Geology* 19:445-467.

[27] Shepard, F.P. and R.F. Dill, 1966. *Submarine Canyons and Other Sea Valleys,* Rand McNally & Company, Chicago, IL.

[28] Normark, W.R. and P.R. Carlson, 2003. Giant submarine canyons: is size any clue to their importance in the rock record? In, Chan, M.A. and A.W. Archer (editors), *Extreme Depositional Environments: Mega End Members in Geologic Time*, Geological Society of America Special Paper 370, Boulder, CO, p. 178.

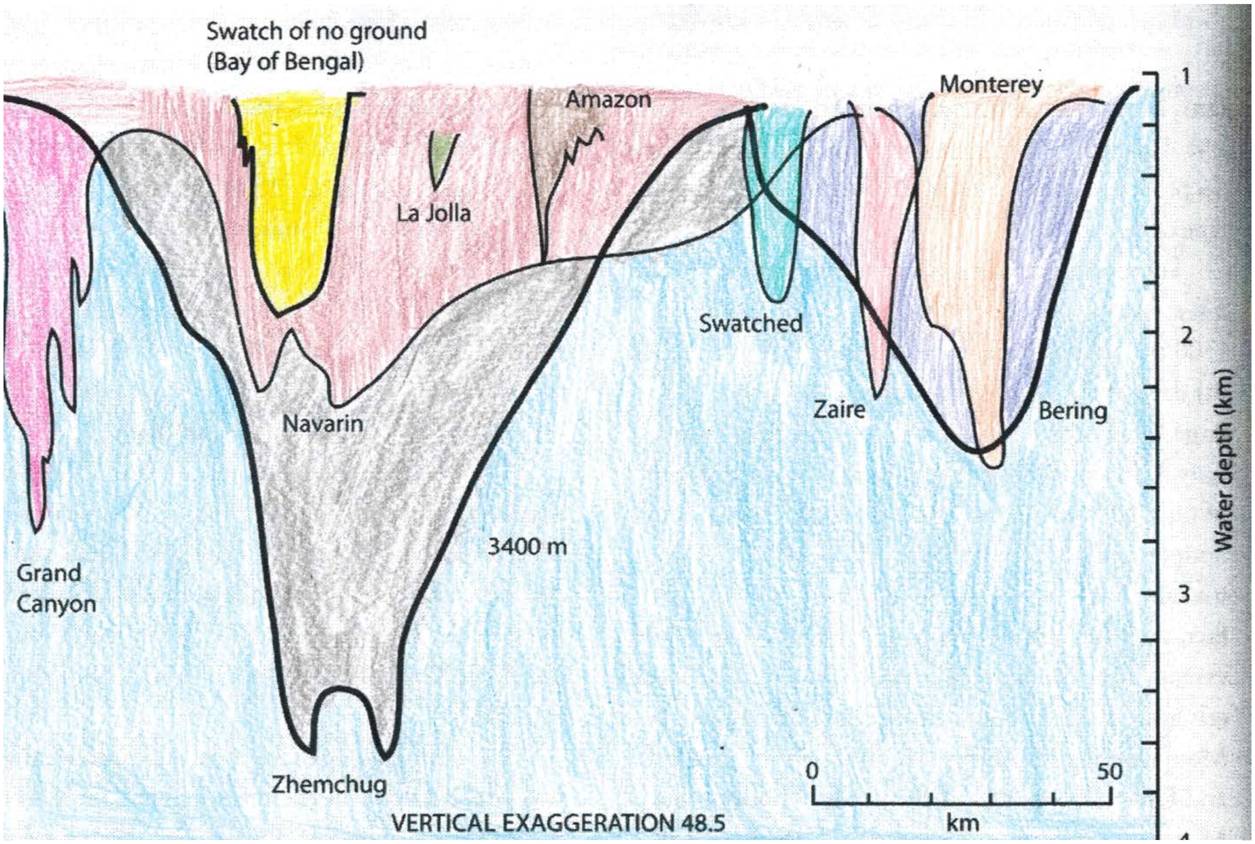

Figure 70.5. Comparison of cross-section near the edge of the continental shelf of various submarine canyons compared to the Grand Canyon (from Normark and Carlson, 2003, figure 2).

The wall height varies down a canyon, and the sides are rarely the same. The average maximum height of the walls is about 3,000 feet (915 m); greater than the average of land canyons.

According to Shepard and Dill, the Great Bahama submarine Canyon has walls that slope up to low islands from a depth of 14,060 feet (4,287 m) below sea level![29] It is thought to have the greatest wall height of any canyon, but since it is not perpendicular to the shoreline of a continent or large island and begins in deep water its origin is probably different from the rest of the submarine canyons.[30]

Excluding the Great Bahama Canyon, the submarine canyon with the highest walls is in the Capbreton along the northern margin of Spain in the Bay of Biscay. Its maximum height is 9,840 feet (3,000 m).[22] Zhemchug Canyon along the Bering Sea slope is a close second at 8,530 feet (2,600 m) high.[25]

The Volume

The largest submarine canyons in the world by volume are found at the outer continental shelf of the Bering Sea about 375 miles (600 km) from land.[24,25,31] There are seven large canyons

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[29] Shepard and Dill, Ref. 27, p. 228.
[30] Shepard and Dill, Ref. 27, pp. 191-198.
[31] Carlson, P.R. and H.A. Karl, 1988. Development of large submarine canyons in the Bering Sea, indicated by morphologic, seismic, and sedimentologic characteristics. *GSA Bulletin* 100:1,594-1,615.

in all, Figure 70.4 shows five of them. They represent volumes of sediment removal that are ten times any other submarine canyon in the lower 48 states. Table 70.1 shows the volumes of the largest submarine canyons in the world along the Bering outer shelf and slope compared with several well-known canyons. Zhemchug Canyon holds the world record volume of eroded sedimentary rocks at 1,415 mi^3 (5,800 km^3).

Rank	Canyon Name	Canyon volume (km^3)
1	Zhemchug, Bering slope	5,800
2	Navarin, Bering slope	5,400
3	Bering, Bering slope	4,300
4	Swatch of No Ground, India	2,950
5	Congo, West Africa	2,300
6	Middle, Bering slope	1,800
7	Pervenets, Bering slope	1,700
8	Pribilof, Bering slope	1,300
9	Kamchatsky, Russia	830
10	St Matthew, Bering slope	740
11	Monterey, California	450
12	Astoria, Oregon	425
13	Hudson, U.S. East Coast	300
14	Wilmington, U.S. East Coast	70
15	La Jolla, California	10

Table 70.1. Volume of the largest submarine canyons in the world along the Bering outer shelf and slope compared with several well-known canyons (from Karl et al, 1996, p. 309).

Other Amazing Properties

The majority of canyons are sinuous, and a significant number gently curve. Many meander, including the 190-mile (300-km) long Capbreton Canyon.[22] A few canyons even show cut-offs of meander loops similar to rivers.[32] Two canyons surveyed by Shepard and Dill showed right-angled bends![27] A majority of surveyed canyons had tributary canyons that entered the main canyon at an acute angle, similar to land canyons. These features are similar to the properties of rivers and indicate that many of these properties can be cut underwater, as would be predicted to have happened during the Flood. Most submarine canyons are cut into sedimentary rock, but remarkably, a significant number are cut in igneous rock, mainly granite.

Submarine canyons are generally V-shaped, giving the indication of youth. Several have vertical walls. A few canyons actually have overhanging walls, like upper Scripps Canyon[33] and upper San Lucas Canyon which are cut in granite off the southern tip of Baja California.[34] Overhanging walls likely happened when the bottom side-walls of the canyon were eroded by turbidity currents that are often detected cascading down submarine canyons. Turbidity currents are bottom hugging currents of sediment that move rapidly down a slope.

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[32] Krastel, S., T.J.J. Hanebuth, A.A. Antobreh, R. Henrich, C. Holz, M. Kölling, H.D. Schulz, K Wien, and R.B. Wynn, 2004. Cap Timiris Canyon: a newly discovered channel system offshore of Mauritania. *EOS* 85 (42):417, 423.
[33] Perkins, S., 2005. Hidden canyons: vast seabed chasms carved by riverlike processes. *Science News* 167:9-11.
[34] Shepard and Dill, Ref. 27, pp. 103-114.