Pillars of Fire, Poison Gas—and Gobs of Oil, Too

The Caspian's geopolitical stardom belies its humble origin 10 million years ago as a brackish, landlocked remnant of the long-gone Tethys Sea. Born in an era of violent tectonic activity, the Caspian remains a seismic hot spot today where oceanic crust creeping northward thrusts beneath continental crust underlying the Caspian's upper basin. The result is a hellish seascape, wracked by earthquakes and riddled with hydrocarbon seeps and mud volcanoes, that poses a huge challenge for oil extraction—and offers loads of scientific puzzles. "To say the geology is well understood is far from true," says geologist Mike Simmons, managing director of CASP, a research institute in Cambridge, U.K., that has done extensive fieldwork in the Caspian.

One complex phenomenon that scientists are still trying to fathom is the Caspian's wildly varying sea levels. Levels had dropped so low about 5.5 million years ago that the lake shriveled to little more than a desert puddle in its southern basin. "It must have been a bizarre and unique environment," says Simmons. Unstable sea levels continue to be a hallmark, rising more than 2 meters between 1978 and 1994 followed by a steady decline since. Fluctuations in evaporation rates and the flow of the Caspian's tributaries can only partly explain sea-level dynamics.

A peculiar topography presents its own set of challenges for both the sea's denizens and oil companies. The Caspian is only 10 meters deep on average in the stable northern basin, but it reaches more than 1 kilometer in depth in the southern basin. Thanks to "one of the most rapid subsidence rates known on the planet," Simmons says, sediments reach a whopping 25 kilometers thick in parts of the southern basin. As new sediment piles up, water trapped in the clayey lakebed comes under crushing pressures. The clays flow like pressurized fluid, moving upward through fractures in the sediment. The mud escapes from cones—"mud volcanoes"—that can grow so tall that they form islands in the deep waters. Geologists take a keen interest in what mud volcanoes can reveal about the Caspian's underbelly, as the cones disgorge rock from many kilometers deep. "They provide us with precious data," says Simmons.

Geological wonderland. A CASP researcher samples one of the Caspian's tamer mud volcanoes.

The majority of the Caspian's 220 mud volcanoes burble meekly. But a few should not be messed with. Last October, for instance, a cone erupted violently south of Baku, sending muck, rocks, and flaming gases dozens of meters into the sky—the ancient Zoroastrians' pillars of fire. In 1959, one monster on the Markarov Bank reportedly shot flames and debris an astounding 10 kilometers into the air and gouged a half-kilometer-wide crater in the lakebed. "You cannot predict when they are going to erupt," says geophysicist Mike Bilbo, British Petroleum's Caspian external affairs chief. Drill rigs can't sit too close to the mud volcanoes, which destabilize the lakebed around them—as the Soviets discovered after losing several rigs.

The North Caspian is no less daunting. The oil there is also under high pressure, and it's sour: It's mixed with poisonous hydrogen sulfide gas. "The technical problems are immense," says Gregory Ulmishek of the U.S. Geological Survey in Denver. "But so is the prize," he says: an estimated 23 billion barrels of oil yet to be discovered.

Oil firms and ecologists alike dread an accident in the newly discovered Kashagan field off Kazakhstan, which could release tons of hydrogen sulfide into the shallow northern waters. Such an ecological nightmare could overshadow the decades of leaks and spills from the South Caspian's Soviet-era wells, some of which are still pumping crude oil. At these operations, says Bilbo, "there are no work practices that are recognized in the West in terms of environmental controls."

But often it doesn't take a human hand to unleash the Caspian's malignant forces. The region's natural hydrocarbon seeps "may have an important role in causing water and air pollution," notes Casey Moore of the University of California, Santa Cruz. Natural seepage, he says, "may be erroneously attributed to human sources"—just one of many features of the unruly Caspian that elicit wonder and are impossible to tame.

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But having long outlived the dinosaurs since debuting in the fossil record 200 million years ago, the venerable sturgeon is facing its toughest test yet. The Caspian is home to the world's biggest population of sturgeon. The sea's four major varieties—stellate sturgeon, or sevruga (*Acipenser stellatus*), Russian sturgeon (*A. guldenstadti*), Persian sturgeon (*A. persicus*), and beluga (*Huso huso*)—supply about 90% of the total caviar harvested worldwide. It's a lucrative commodity: As *Science* went to press, one firm, Tsar Nicoulai Caviar, was advertising sevruga caviar at $1448 per kilogram. Beluga roe, meanwhile, was fetching more than $2500 per kilogram. Russia alone says it hauled in $40 million last year from caviar exports, although some observers claim that the figure for legal exports was closer to $100 million.

The sturgeon's enemies are legion, but poachers may be taking the heaviest toll. Last year they fueled a shadow caviar market estimated at $400 million, according to Russia's Interior Ministry. Rampant poaching since the Soviet meltdown has sent sturgeon stocks crashing, with beluga numbers less than 10% of what they were 2 decades ago, the government estimates. Last year Russia began working with Interpol to try to crack down on smuggling, but most observers say it will take years, if not decades, to stamp it out. Other factors in the decline include dams on the Volga River that cut off access to spawning areas, and perhaps pollutants that accumulate in fat and may render eggs infertile. "The whole ecology of the rivers has changed," says biologist Ellen Pikitch of the Wildlife Conservation Society in New York City.

Recognizing the seriousness of the situation, the secretariat of the Convention on International Trade in Endangered Species (CITES) got three Caspian nations to agree to a 6-month moratorium on fishing sturgeon last June. Some experts contend that the ban, which ended on 1 January, did little