

## EFFECTS OF AN EARTHQUAKE IN A MINE AT TOMBSTONE, ARIZONA

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Evidence regarding the degree to which earthquake vibrations are perceptible below the surface of the ground and the physical effects of such vibrations seems to be very meager. This is doubtless due to the fact that people who have had such experiences seldom take the trouble to record them. The writer has been told by persons who have been in mines during earthquakes of quite marked surface intensity that nothing was felt underground; while others, in other mines, have reported that they were plainly felt. It is possible that both are right, and that the varying testimony is due to differences in rock structure, the neighboring rocks in one case transmitting the vibrations readily and in the other absorbing and deadening them, or possibly they are locally cut off by intervening cushions of inelastic material such as decomposed dikes. It is conceivable also that wave interference may locally cause stationary spots, or there may be nodes. Such phenomena are understood to be recognized by seismologists regarding the surface effects.

The writer has had the experience of being in a mine during an earthquake and it is to record a few observations regarding this experience that these notes are made.

In May, 1887, there was a succession of earthquake shocks, felt pretty generally throughout the southwest, but in more pronounced degree in southeastern Arizona, and to a still greater extent in northern Sonora, Mexico, where considerable damage was done, and where it would have been very great if there had been many large structures in that locality. It was found later that the center of the disturbance was in Sonora, over 100 miles south of the international boundary line. A committee of investigation was sent down to report on the effects of the earthquake, and, as I remember, found a very extensive fracture, open in places, and with vertical displacements of many feet in the walls at intervals. Doubtless the report of the committee can be found in the papers of that time. An account was printed in the

*Engineering and Mining Journal* of June 11, 1887, covering surface effects in southern Arizona.

It appears to be well established that the vibrations were of sufficient intensity to constitute a fair working test of what earthquake vibrations might be expected to do to mine workings in their paths. At that time the mines of Bisbee and Tombstone were very extensively opened, and there were many miles of underground workings, including many large cavernous open stopes in the limestone, with little timbering. Notwithstanding these conditions, the actual damage underground was only trifling, while on the surface the shocks were sufficient to cause plaster to fall, to throw down chimneys, and disarrange foundations so as to require the resetting of engines.

Up to that time I had always understood that earthquake vibrations were not very perceptible far underground, but I found this to be a great mistake in some cases. In company with an assistant I was engaged on some survey work in a mine at Tombstone in a large inclined open stope about 150 feet below the surface. The first warning was a heavy roaring noise, followed almost immediately by the beginning of vibration which seemed to culminate in a very pronounced jolt. The first impression was that there had been an explosion of some kind, but I quickly recognized the vibrations for what they really were, as I had felt earthquakes before. The loosened rocks from the hanging-wall crashed down with much noise, striking sparks as they came in contact with the hard footwall, and for a few moments our situation was one of considerable danger and such as to leave a vivid mental impression.

At another mine where men were working at a depth of 500 feet, cutting out a chamber in hard limestone about a hundred feet from the shaft, they dropped their tools and rushed for the station, where they needed no urging to come up. They said they thought the mine was caving in, as everything seemed to be moving. One of the men told me that he was standing in a drift in hard white limestone; that he felt impelled to brace himself against the walls to maintain equilibrium, and that he distinctly saw a wave or deflection in the solid rock approach and pass him. He is not an imaginative person, and he has repeated this statement to me within the past few days, as he lives in Los Angeles, and I sought him to question him again about his experiences and sensations.

A man went to find a miner who was working alone in a very soft raise being put up from the 500-foot level, but strange to say, he had noticed nothing unusual and took the warning called up to him as a joke, refusing to come down. The vibrations so apparent in the hard rock seemed to have been absorbed by the softer, spongy rock.

So far as the writer's experience goes, it seems to show that, while earthquake vibrations extend at times to depths of several hundred feet in very pronounced degree, there is little to be feared in the way of material damage to mines from them even when of considerable intensity.