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JULY 16th NUCLEAR EXPLOSION:
PERMANENT EARTH DISPLACEMENT

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ABSTRACT

A measurement was made of the permanent earth movement in the neighborhood of the tower caused by the nuclear explosion at Trinity. The crater was apparently formed by a compression phenomenon and was noted to be much shallower than craters formed by ordinary high explosives. Scaling up existing information on the radius of craters, the TNT equivalence of the nuclear bomb is given as 10,000 tons to within 50 percent. Observations were made on the damage in the crater region and suggestions are given as to the nature of structures which might be expected to withstand the blast close to the gadget. It is also noted that, despite previous opinion to the contrary, it is apparently possible to reduce greatly the volume of earth blown away by the blast by suitably protecting the ground.

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Experimental Arrangement

Steel stakes two feet long and one inch in diameter, provided by J. Coon, were located at various distances from the center of the tower base along two mutually perpendicular lines by a group under Captain Davalos.

The stakes were driven vertically into the ground allowing only the top half inch to protrude. A survey was made of these stakes with respect to elevation and distances between the stakes on a given line located 1,000 feet from the center of the tower base in a southerly direction. Surveyors from the Albuquerque corps of engineers did the pre-shot measurements; Los Alamos Post surveyors did the post-shot measurements. Fig. 1 is a detailed map of the survey including the distances and elevations before and after the shot, as well as comments on the appearance of the stakes after the shot. Fig. 2 gives a pre- and post-shot sketch of a tower base.

Pictures of the stakes (Fig. 3) taken after the shot indicate the marked deformation caused by the blast. Fig. 4 is a general view of the central crater region. It is clear that because of the deformation of the stakes and the local irregularity of the ground caused by the blast, the measurement of an elevation is affected by ignorance of the point on the stake at which to measure. Pre-shot measurements were taken to an accuracy of .01 feet. Post-shot measurements cannot be relied upon to better than a few tenths of a foot because of the irregularity of the ground and the marked deformation of the stakes.

In view of the fact that the crater seems to have been formed mainly by compression of the ground, it seems worth recording that a well sunk at the zero point before the tower was built indicated a ground structure comprised of sand and gravel from a depth of zero to 180 feet. Borings of a ground well at North 1000 yards showed sand and gravel from zero to 120 feet and sandy clay, or sand, or clay, alone, from 120 to 365 feet. [redacted]

Because of the radioactivity in the region of the survey, the two surveying crews did their job each accompanied by a radiation monitor on August 12 and 13, four weeks after the shot. They spent about three hours in the contaminated area; the highest dosage recorded was 4R. Some idea of the extent of the area measured can be obtained from the included marked air photo (Fig. 5).

Results

The most marked feature of the crater was its great width, approximately 1,100 feet, and its small depth, about 9-1/2 feet at the center. Contrary to expectations, based on the 100-ton shot, which was located on a tower at a scaled elevation corresponding to 5000 tons of TNT at 100 feet, the crater was clean swept and the ground hard packed. Roads leading into the crater from north, west and south, were merely depressed with the surrounding ground up to a distance of approximately 150 feet from the center of the tower base. The volume of the crater as calculated from Fig. 8 is 1.3×10^6 ft^3. Within the 150-foot circle the surface was completely disrupted.

Small spheres of fused earth were found in the outer part of the fused region. Since these spheres are of higher specific activity than the surrounding fused soil we can conclude that they did not originate at the points where they were found. In this connection it might also be noted that the radioactivity in the very center of the crater was small compared to the activity further from the center. These results seem consistent with the fact that the center of the crater was actually gouged since these small spheres may possibly have resulted from the solidification in air of the melted earth blown out from the center by the blast.

From 150 feet outwards, a thin layer of earth was removed by the blast. The volume of earth blown away from 0 to 1000 feet from the center, as calculated from the length of exposed earth stakes, is roughly 4×10^5 cubic feet or about 30 percent of

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the total crater volume. It would appear then, that the crater was largely formed by compression rather than gouging action of the blast.

If it is assumed that the crater is formed by compression of the ground to within a depth of 20 feet, an increase in density of ~10 percent would be required in the cratered soil. No soil-modulus experiments are available to test this estimate but the density increase required seems reasonable.

Figs. 6, 7, and 8 are plots of the ground contours before and after the test. The first two simply give the elevations taken on lines running from N to S and E to W , referred to, the 1,000-foot point. The third plot refers the changes in elevation to the pre-test elevations. Inspection of this third plot shows the crater to be essentially symmetrical. The radius of the crater, as seen from the air photo, is about one-half the radius of the circular area over which the ground is fused.

The radius of the crater can be related, in a rough empirical way, to the TNT equivalence of the nuclear explosive. Scaling up the radius of the crater formed by the 100-ton shot, and the crater information given in the Weapons Manual, we can conclude that to within 50 percent the blast performance of the gadget was equivalent to that of 10,000 tons of TNT placed at the same height. It should be noted that the depth of the crater was much less than that given by the empirical rule which states that the depth is approximately one-quarter of the radius.

The horizontal movement of the ground was quite different from that predicted on the basis of the 100-ton test. In the case of the 100-ton test we may recall that the ground moved horizontally in a very peculiar way, some stakes moving towards the center and others away. In the nuclear bomb test, however, it was noticed that, within limits of experimental error the ground moved towards the center in every case. Previous to the 100-ton test, it was expected, on the basis of many trials made elsewhere with smaller charges, that all horizontal earth movement would be outward from the blast.

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This result seems reasonable in that the ground would be expected to be pushed away by the blast. We have as yet had no success in interpreting the peculiar earth movement obtained in the 100-ton test. The result in the gadget test might be explained by assuming that the ground behaved like a membrane in which the points were drawn towards the center as the membrane was deformed. An attempt was made to check this hypothesis by observing the positions in the ground of the earth movement stakes; but the stakes were too short to be deformed in a manner definitive of the mode of deformation suffered by the earth. One would expect, for example, to find the part of the stake remaining in the ground to be bent towards the blast and the part of the stake out of the ground be blown away from the blast (Fig. 9). The latter was observed but the former is expected to be slight, and actually was not detected, although it might have been observed at points very close to the center if the stakes had not been blown out of the ground. It is somewhat difficult to understand why the ground should act like a membrane since Trinity dirt has no apparent tensile strength. An alternate hypothesis is that surface layers, directly under the blast, are compressed and flow outward; but no data are available to check this conjecture, and since the surface and sub-surface soil have the same structure (sand), there seems to be no good reason for the surface not to move outward with the sub-surface layers.

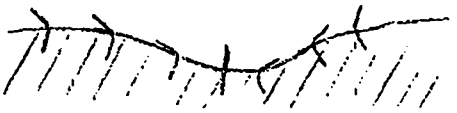

Fig. 9

The four tower bases were originally placed with their tops two feet above the surface of the ground, and their bottoms seven feet below the surface of the ground. After the blast it was noted that, although the parts of the bases originally above ground were shattered, the entire base structure was pushed down with the ground to a depth of from five to seven feet. The steel work remained intact below the point which was originally encased in concrete. At this point it was apparent that the steel had been burnt off by the explosion (see Fig. 2). It might be useful to excavate the stumps of the tower base and examine the condition of the base left buried after the blast. This suggestion is being considered.

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Inspection of the damaged tower base, which was located at the close distance of 100 feet from the gadget, leads one to conclude that it is possible to build underground structures which might be expected to withstand demolition by nearby detonation of a gadget. This is borne out by the fact that the position of the base, which was originally underground, was, despite fissures and spoiling of the concrete, essentially intact, and further, that the four tower bases were sunk by the blast approximately the same amount. It can be concluded on the basis of damage to Trinity shelters, that any reasonably strong structure, i.e., heavy earth shelter, such as the 10,000-yd structures at Trinity, would be expected to be safe for human occupants directly under the gadget in case of a comparatively distant air burst ($\sim$ 2000 feet) such as used over Japan. On this basis it appears possible to provide shelter for human beings at a distance of 1500 feet, which can be expected to withstand an air burst extremely close to the ground. From this it appears that a shelter could be designed which would make it possible for human beings to survive within 500 feet of the bomb. This guess is based on the appearance of the tower bases which were only 100 feet from from the bomb. This does not apply to bombs buried in the earth.

Suggestions for future tests

If in any future tests of nuclear bombs it is decided to mount the bomb on a tower, as at Trinity, the earth movement might be studied more adequately if steel stakes three inches in diameter and five feet long were used as earth movement markers. Geological samples should be taken in the vicinity of the shot and tested with respect to density and strength. In connection with the effectiveness of air-burst bombs against sub-surface installations, markers should be buried at various distances from the shot and their location carefully noted both before and after the test. It might be well to test the conclusions about sheltering human beings in the neighborhood of the blast by constructing experimental shelters containing test animals, in case it is decided to make a test of another gadget. In addition, various structures simulating

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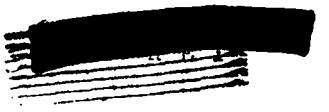


sub-surface installations might well be placed underground at several distances.

In the Trinity test it was found that areas (at greater distances than 150 feet from the gadget) surfaced by macadam were not broken up by the explosion and drawn into the rising cloud as dust.

Since the dust is undesirable first in that it interferes with nuclear measurements and second in that it presents a hazard as a radioactivity carrier which precipitates from the cloud at a later time, such coating of the ground would appear to be extremely useful. If the bomb were placed on a tower about 250 feet high and the ground were coated by macadam it seems reasonable to expect that the quantity of dust raised would be negligible.

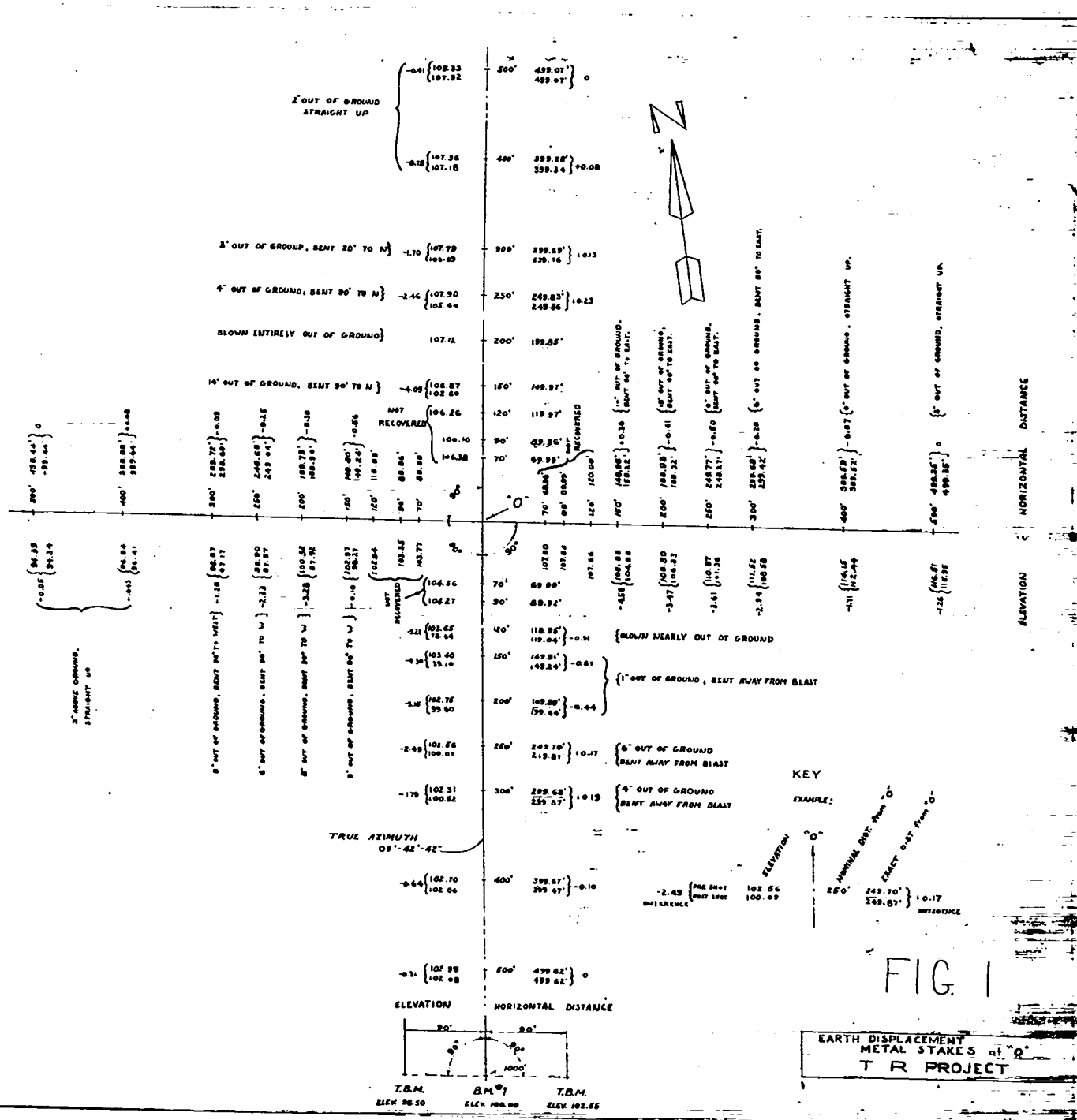
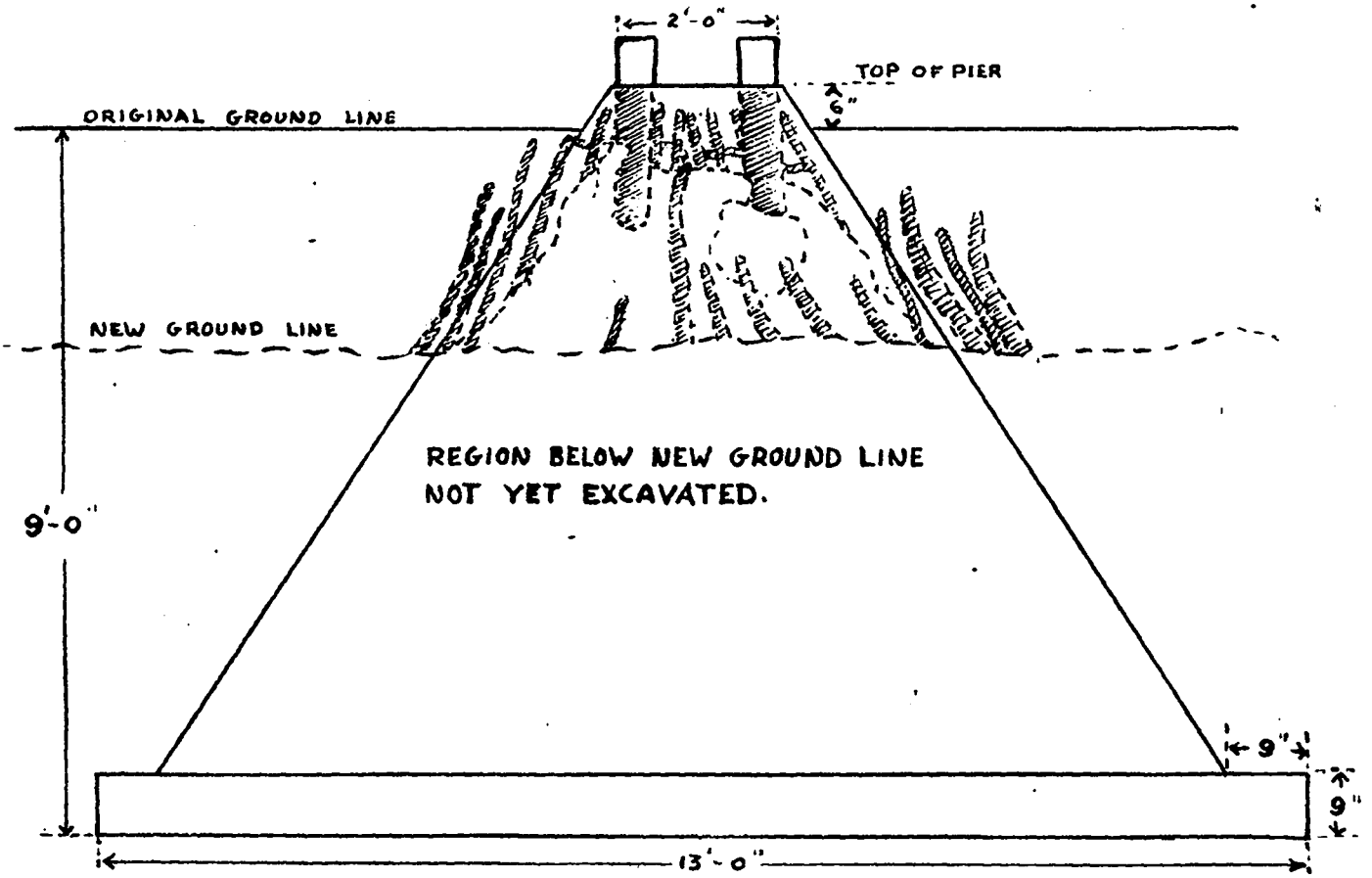
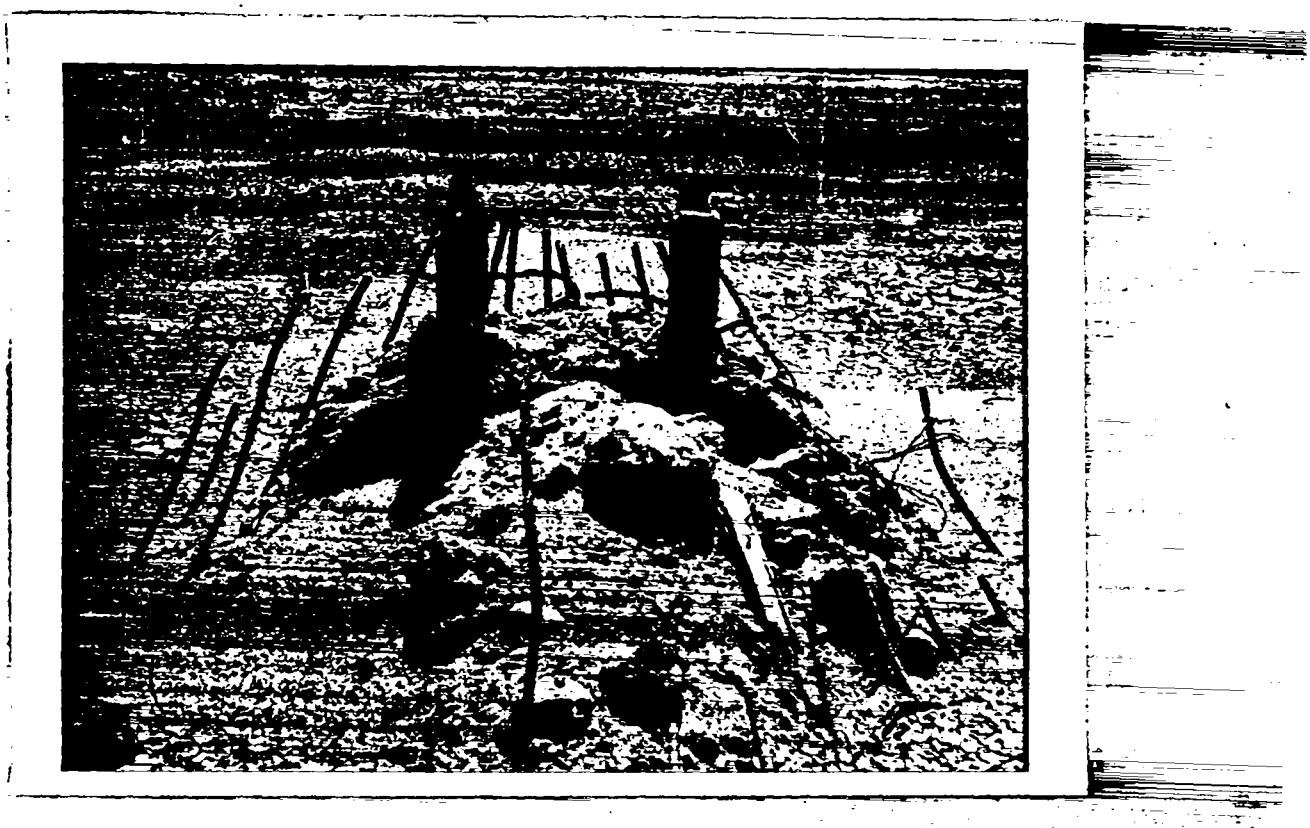


FIG. 1

FIG. 2

REINFORCED CONCRETE TOWER PIER





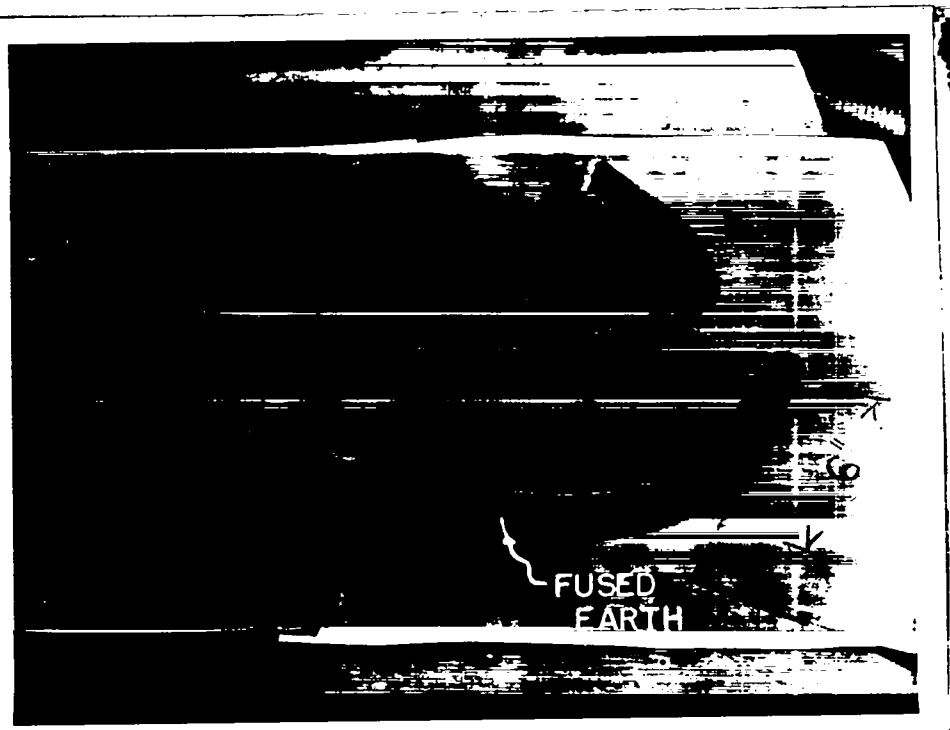


Fig. 3. Permanent-earth-movement stakes.
These stakes were initially buried at 250 and 300 ft. from the center to within half inch of the top. When recovered the stakes were exposed to the depth indicated by the coating of fused earth.

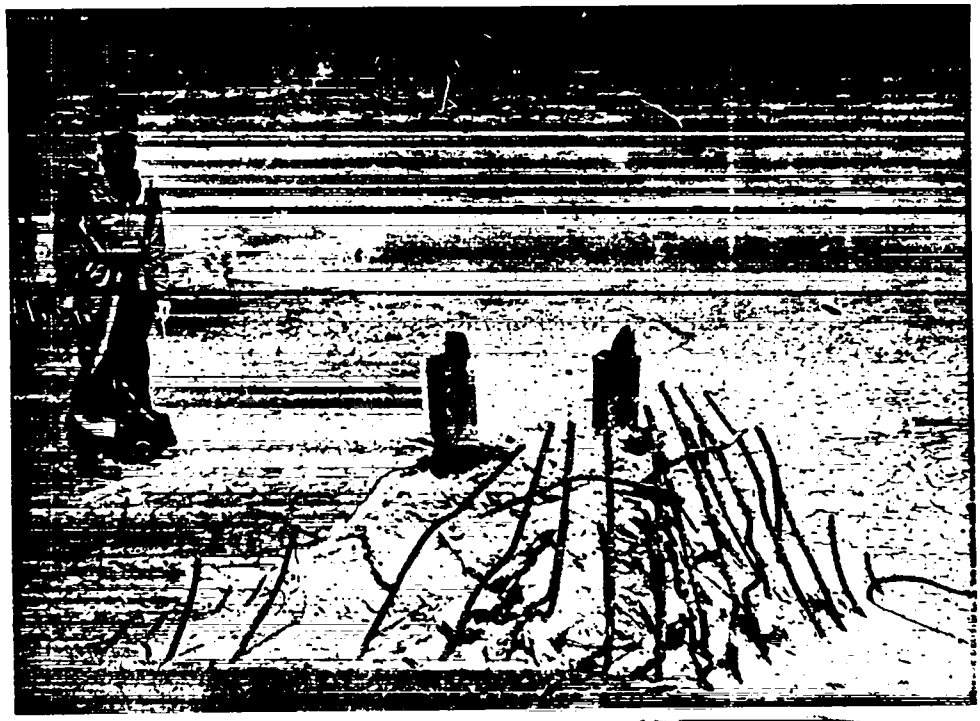


Fig. 4. The Center of the Crater.
The distance between the tower base stumps is 28 ft.,8 inches.

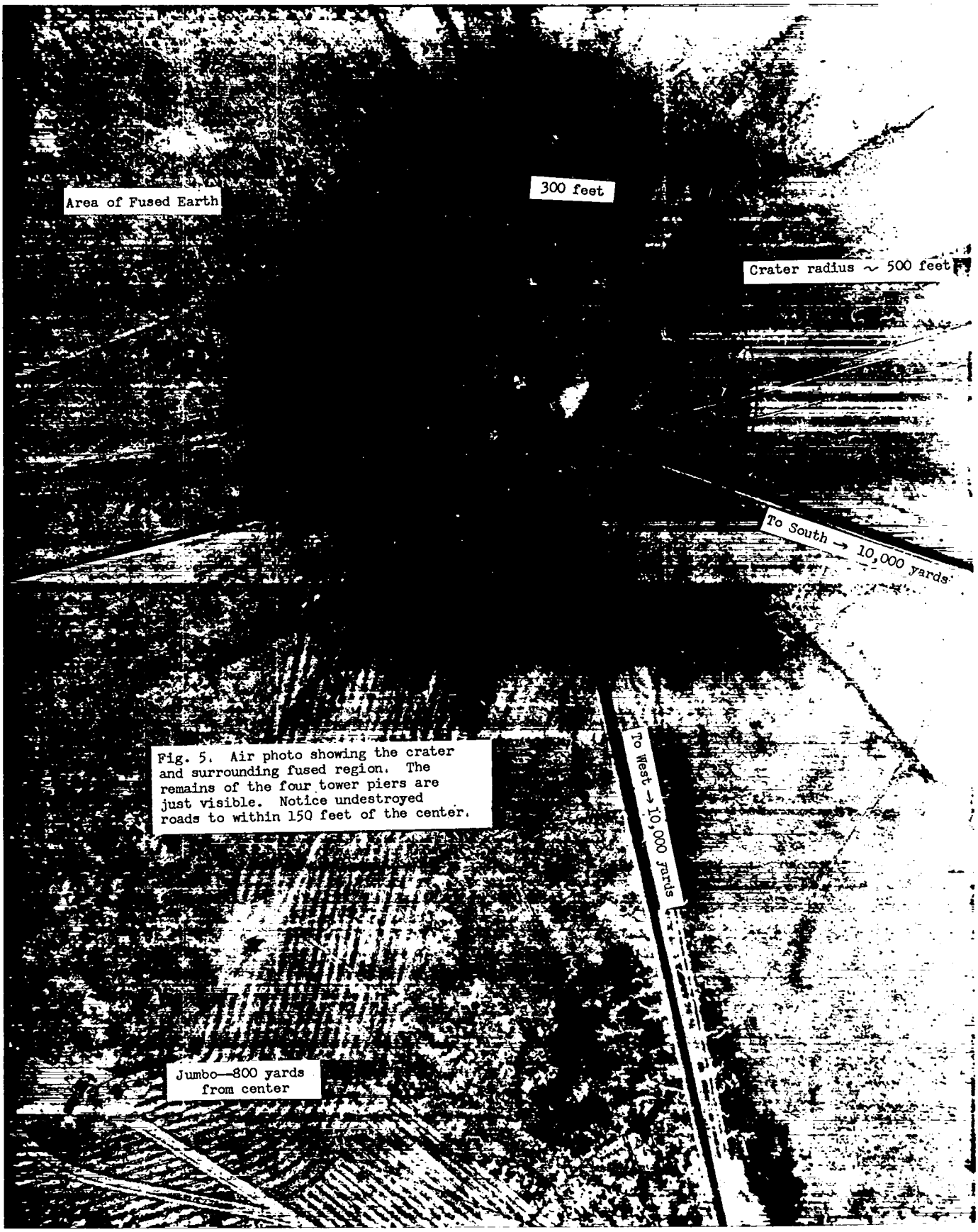
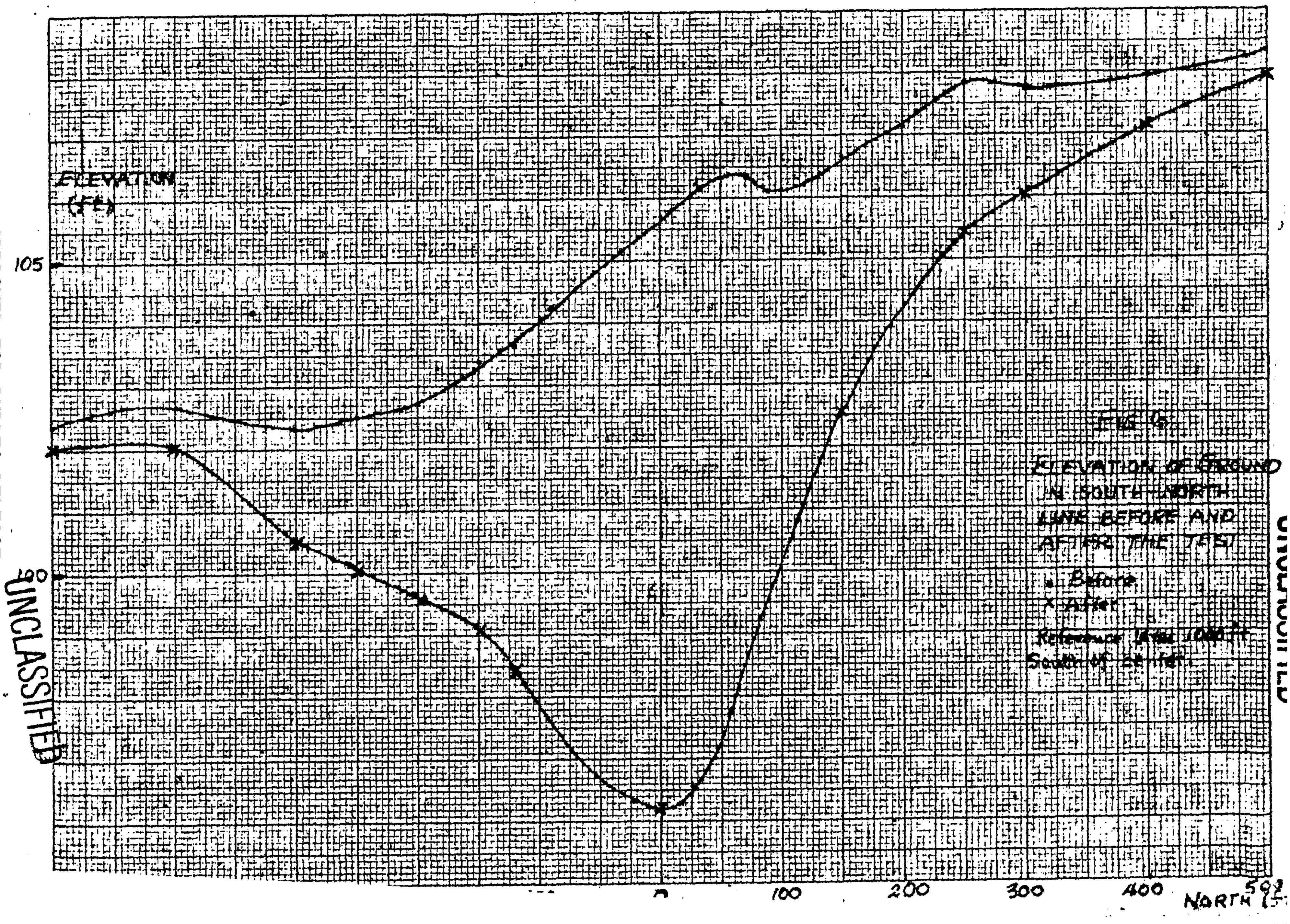


Fig. 5. Air photo showing the crater and surrounding fused region. The remains of the four tower piers are just visible. Notice undestroyed roads to within 150 feet of the center.



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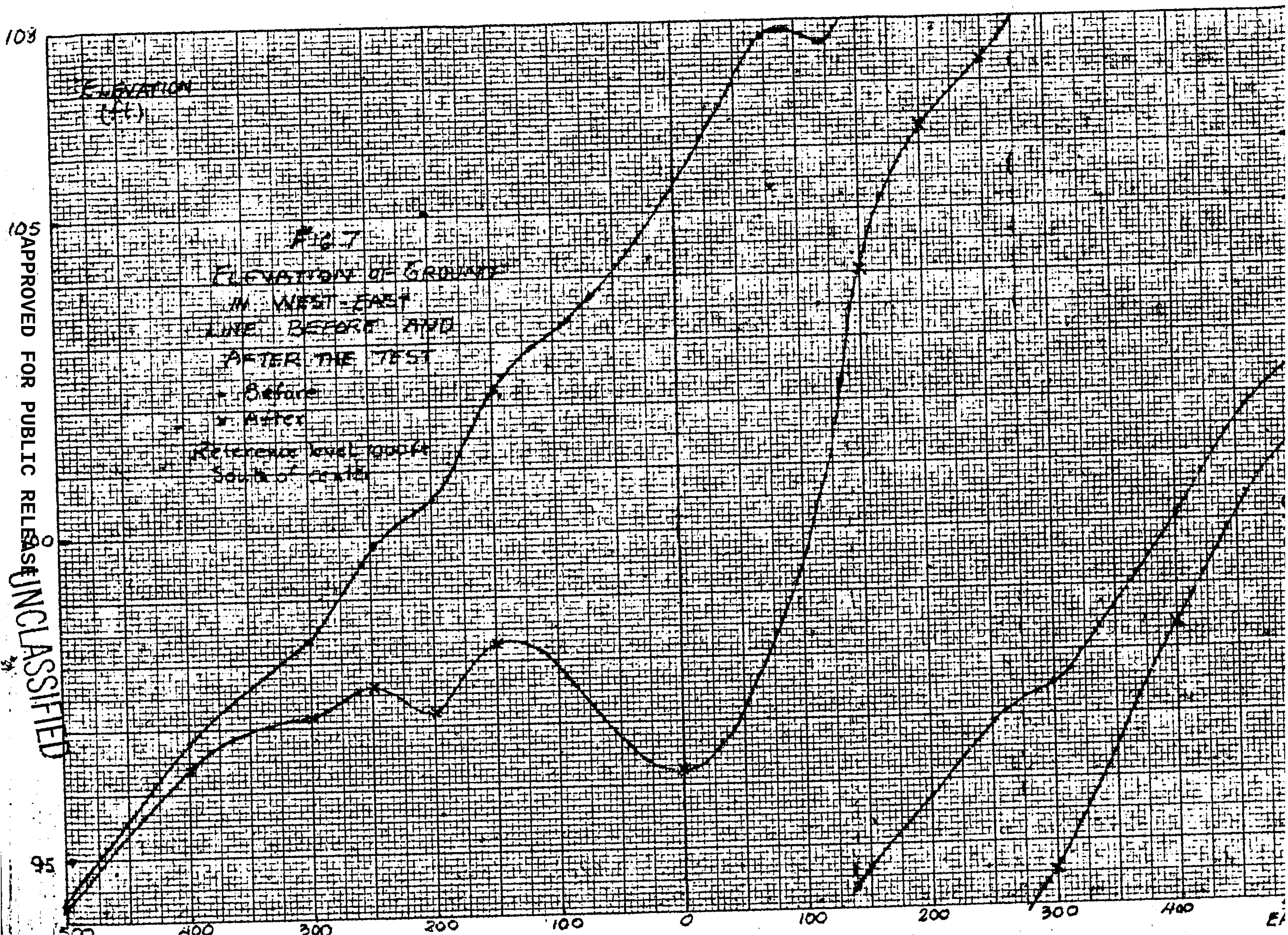

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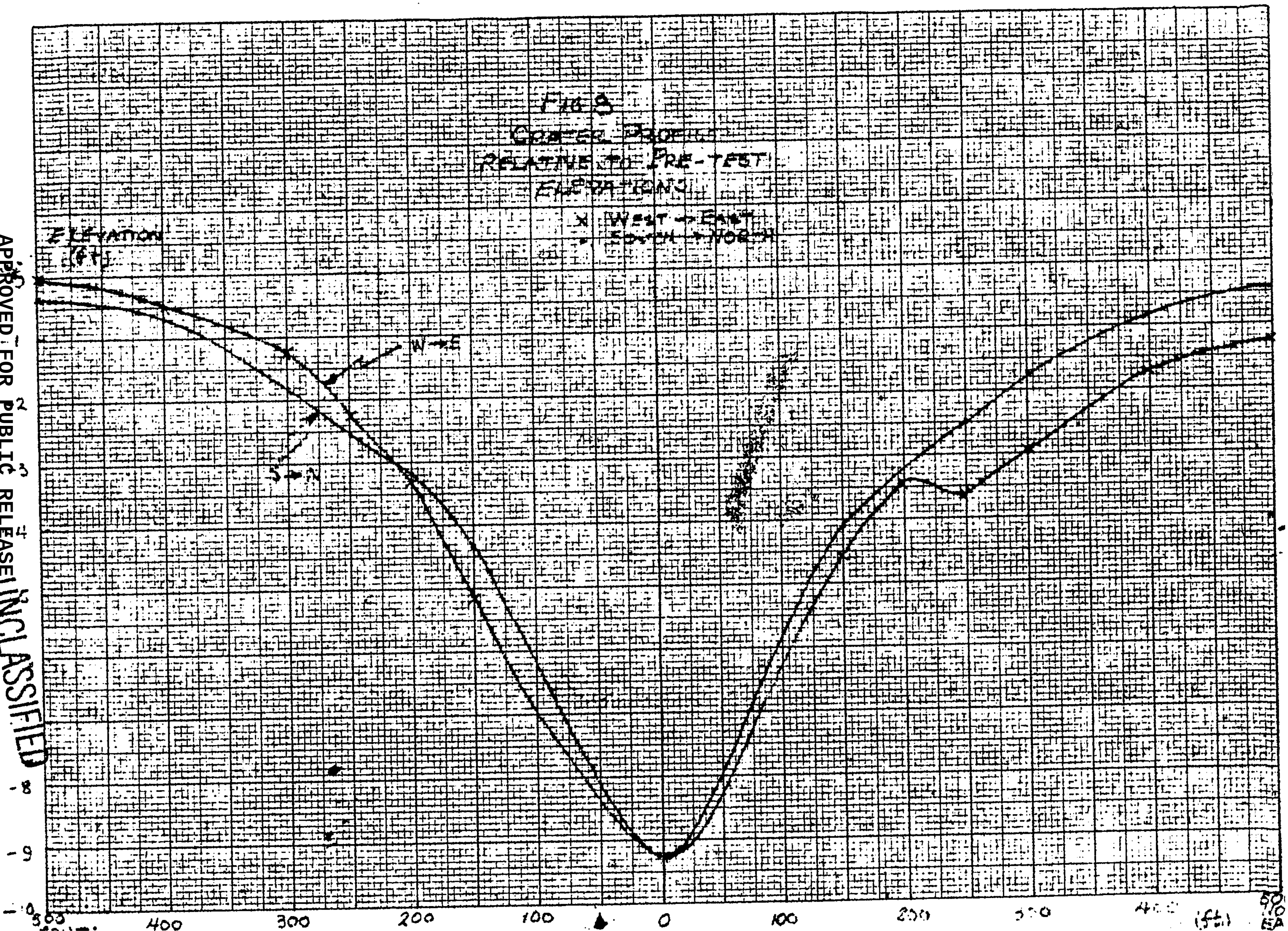

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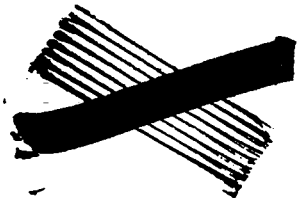

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