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7.4 Epicenter location and cratering at the Novaya Zemlya underground nuclear test site

In 1989 the Norwegian Institute of International Affairs (NUPI) started a satellite study of the northern underground nuclear test area on Novaya Zemlya. Results from this study were published in Skorve and Skogan (1992). Early in this work, using Landsat TM images, one craterlike feature was found close to the southwestern mountain slopes of the Matochkin Shar Strait. SPOT panchromatic 10 m resolution images were purchased, and these revealed three features, most probably craters that were created by underground nuclear explosions. This was unexpectedly confirmed when German aerial photographs of the Matochkin Shar from the summer of 1942 became available. The craters did not show up on these and thus proved that they were formed sometime after 1942. Fig. 7.4.1 is a spot photo from 1989 of the test area, showing the three craters. The aerial photo taken in 1942 is shown in Fig. 7.4.2.

The craters are lined up in a row approximately parallel to the Matochkin Shar coast. The northernmost crater ("N" in Fig. 7.4.1) is very well defined, being nearly circular and about 100 m in diameter. The middle one ("M" in Fig. 7.4.1) is by far the largest and appears roughly elliptical, measuring about 220 x 270 m. The reason for its irregular shape is probably that the epicenter is very close to the crest of the steep mountain slope down toward the Matochkin Shar coast. Following the underground explosion, parts of the mountain above the detonation center, big blocks of rock and boulders, slid down the slope. The crater to the south ("S" in Fig. 7.4.1) is about 75 m in diameter and is situated on a quite level mountain slope, not steep, facing the Shumilikha river. The obvious question was which underground explosions created these three craters. To check this, we plotted the locations of underground nuclear explosions on a map of the area. For underground tests made before the TTBT-agreement became effective in 1976, the epicenter locations were taken from Lilwall and Marshall (1986), while for the later ones, NORSAR provided the data. However, the uncertainty involved proved to be too large to make it possible to connect the craters to specific underground nuclear explosions in that area.

The Joint Epicenter Determination (JED) method, described in Lilwall and Marshall (1986) paper, that was used to improve location of epicenters, attracted our attention. The JED-method requires that at least one of the epicenters in the test area be restrained to predetermined values. The difficulty on Novaya Zemlya is that there is no information on true locations. The explosion on 29 September 1976 (event 14 in Lilwall and Marshall (1986)) was chosen as the constrained epicenter for the northern test site. It is well recorded and centrally placed with respect to the distribution of epicenters. Since the true location of event 14, "the origo point", is also uncertain, we thought the location of the craters found close to the Matochkin Shar could be used as new constrained epicenters for the northern test site to obtain more accurate location of the underground nuclear explosions on Novaya Zemlya. Two requirements have then to be met: determination of the exact coordinates of the crater centers and identification of which explosions caused the formation of the three craters. As mentioned earlier, the seismic location is too inaccurate to relate specific epicenters to the three craters. However, some time after the NUPI study (Skorve and Skogan, 1992) was published in 1992, collateral information emerged with information on which specific nuclear explosions caused the formation of the three craters. Additional information is found in Matzko (1993), as it contains data on scaled depth of burial (SDOB) for the underground nuclear explosions on Novaya Zemlya. For all the three explosions that caused the formation of craters, SDOB was 90 m according to Matzko (1993).

The approximate depth of explosion can be calculated from the formula: $D = mY^{1/3}$, where D = approximate depth of explosion in meters, m = the scale depth in meters (=90 m) and Y = yield in kilotons (TNT equivalent). Measurements and calculated data on the Novaya Zemlya craters and their associated explosions are collected in Table 7.4.1. The yields given in this table are from Matzko (1993).

The location of the crater centers on SPOT satellite images can be measured with an accuracy of 2-3 pixels (20-30 meters). Unfortunately, it is presently not possible to transform this to the same degree of cartographical accuracy. This is due to the total lack of good topographical maps of the Matochkin Shar area. The best available map is at the scale of 1:500,000, which is clearly inadequate.

One alternative way to improve the geographical location of the craters is now being tried. The method uses the pixel and line coordinates measured on SPOT satellite images combined with ancillary data that is available on the leaderfile on SPOT digital data tapes. These are measurements made during the imaging process and include satellite position, satellite velocity, satellite attitude velocity, look angle of the imaging instrument and observation time.

Three digital SPOT scenes of the Novaya Zemlya northern underground nuclear test site were purchased. The pixel and line coordinates of the crater centers were measured for each of the SPOT scenes. The three separate sets of measurements were combined with their associated ancillary SPOT data. This procedure is illustrated for two of the SPOT scenes in Figs. 7.4.3 and 7.4.4. The preliminary results of geographical coordinate determination using this method are presented in Table 7.4.2.

The pixel/line measurements were made by Masahiro Etaya of TRIC, Tokyo, and Johnny Skorve, NUPI, while calculation of the crater center coordinates was made by Pål Bjerke, researcher at the Norwegian Defence Establishment (NDRE). The crater center coordinates can be derived by calculating the middle values of the three data sets.

The average inaccuracy of SPOT in this context is about 500 m and relates to uncertainties in satellite position and the look angle of the imaging instrument. Additional inaccuracy is added to this by the perspective effect when doing off-nadir imaging. The size of the effect is determined by the off-nadir look angle and the attitude above the sea level of the area or spot of interest.

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References

Lilwall, R.C. and P.D. Marshall (1986): Body Wave Magnitudes and Locations of Soviet Underground Explosions at the Novaya Zemlya Test Site. Atomic Weapons Research Establishment Rep. No. O 17/86, HM Stationary Office, London, England.

Matzko, J.R. (1993): Physical environment of the underground nuclear test site on Novaya Zemlya, Russia. USGS Open-File Rep. 93-501, Reston, VA, USA.

Skorve, J. and J.K. Skogan (1992): The NUPI Satellite Study of the Northern Underground Nuclear Test Area on Novaya Zemlya. NUPI Research Rep. No. 165, Oslo, Norway.

Crater	Approximate Dimension	Date of Detonation	Approximate Yield of Explosion	Approximate Depth of Explosion
Northern	Circular Diam.=100 m	28 Aug 1972	330 kt	620 m
Middle	Irregular 220x270 m	21 Oct 1967	95 kt	410 m
Southern	Nearly Circular Diam.=70 m	27 Oct 1966	420 kt	680 m

Table 7.4.1. Measurements and calculated data for the explosions associated with three craters described in the text. The approximate depth of explosion is calculated from the scaled depth of burial and yields given in Matzko (1993).

Crater	Pixel No.	Line No.	Crater Center Location	
SPOT Image 24 August 1989				
Northern	2263	1363	54:50:56 40 8146334	73:23:58 431423
Middle	2257	1425	54:50:08 40 8145892	73:23:45 450982
Southern	2230	1518	54:48:40 40 8245343	73:23:26 430176
SPOT Image 29 July 1990				
Northern	5031	4794	54:50:26 40 8146433	73:24:82 431157
Middle	5024	4854	54:49:42 40 8145978	73:23:47 430757
Southern	4989	4945	54:48:15 40 8145425	73:23:28 429948
SPOT Image 17 August 1992				
Northern	1861	3247	54:52:21 40 8145085	73:23:20 432127
Middle	1860	3309	54:51:36 40 8144624	73:23:05 431712
Southern	1831	3401	54:50:03 40 8144127	73:22:48 430874

Table 7.4.2. Crater center locations for the three craters described in the text. The coordinates are estimated from three SPOT scenes, from 1989, 1990 and 1992, respectively. The crater locations are given in geographical coordinates (degrees: minutes : seconds) and in the Universal Transverse Mercator (UTM) grid.

Fig. 7.4.1. This enlargement of a SPOT photo taken in August of 1989 covers the Matochkin Shar strait of Novaya Zemlya from the Shumlikha delta and about 8 km northeastward. The Severny Base is seen in the middle of the lower part of the picture. The craters found on this picture (denoted "N" for northern, "M" for middle, and "S" for southern) are seen as white or partly white spots because of snow left inside their boundaries. (PHOTO: SPOT IMAGE; IMAGE PRODUCTION: TRIC: TOKYO)

Fig. 7.4.2. The area shown on this mosaic of two Luftwaffe aerial photos from 1942 is the same as that of Fig. 7.4.1. There is no trace of the three craters seen on Fig. 7.4.1. (PHOTOS: GERMAN LUFTWAFFE)

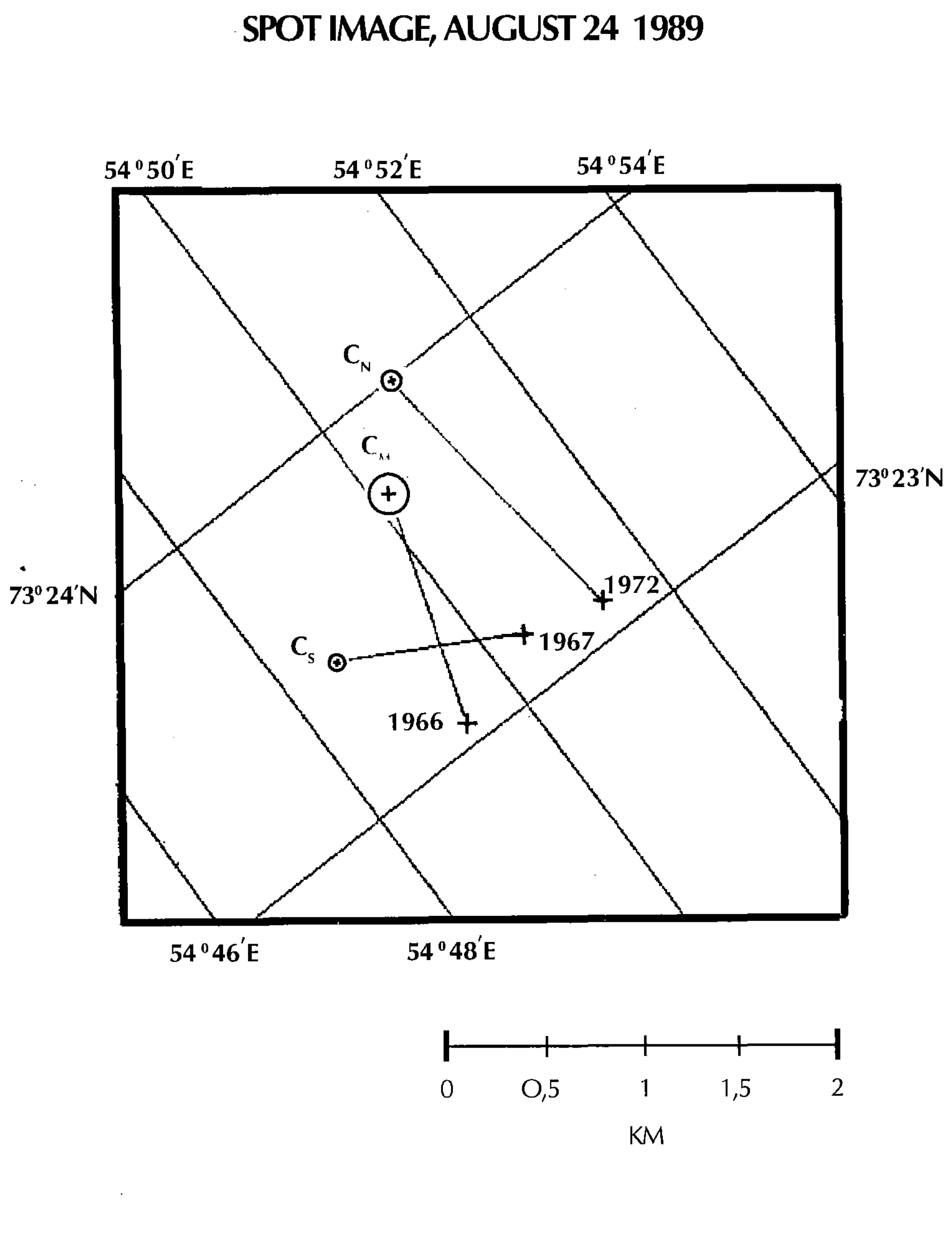

Fig. 7.4.3. Crater center locations based on the SPOT scene from 24 August 1989. The position of the coordinate grid is based on ancillary data available on the SPOT digital data tape, as explained in the text. The epicenters of the associated explosions are from Lilwall and Marshall (1986). Note that the southernmost epicenter location (1966) does not correspond to the southernmost crater.

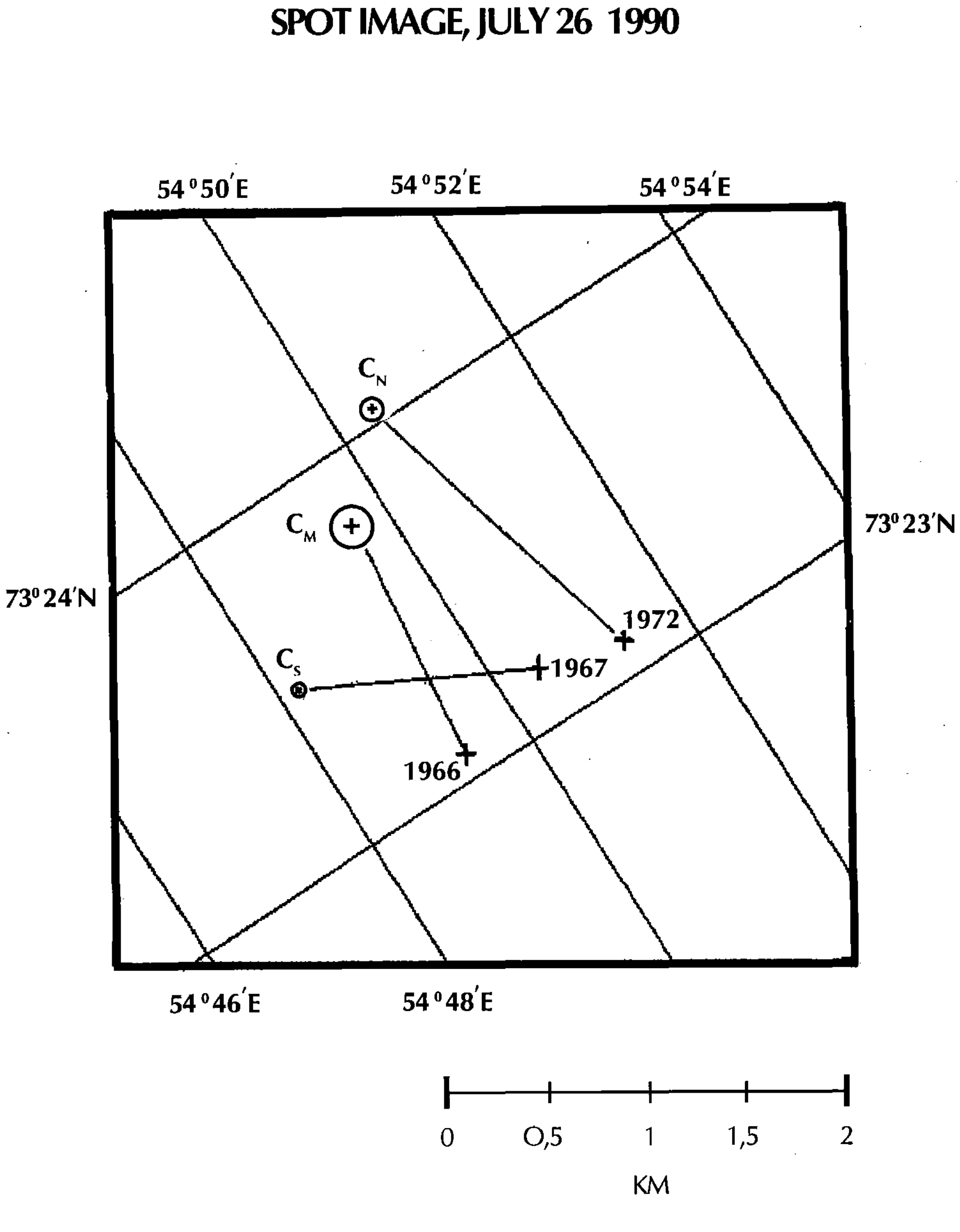

Fig. 7.4.4. Same as Fig. 7.4.3, but here based on the SPOT scene from 26 July 1990.