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Pressure waves recorded in India associated with two well-known meteors

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ABSTRACT. Pressure waves due to fireballs or bolides recorded by Indian observatories by ordinary barographs are discussed. A description of the meteors in general has been given to provide background material. The Tunguska event of 30 June 1908 is discussed with reference to its cometary nature rather than meteoric nature. The Sikhote-Alin fireball of 12 February 1947 and its effects have also been discussed, and velocity of the pressure waves generated by these two meteoric explosions, calculated. A comparison of the pressure waves of the Tunguska event recorded in England and India is made. It has been suggested that the records of sensitive microbarographs of the Shaw-Dines type installed at some selected stations in India to detect atomic explosions would be helpful in the study of pressure waves associated with meteor explosions.

1. Introduction

Meteors are extra-terrestrial bodies of cosmic origin of varying masses, belonging, so to say, to the debris of the solar system, which enter the earth's atmosphere at speeds varying from 10 to 75 km/sec according as the meteor enters the atmosphere against the rotation or in the same direction of rotation of the earth, get decelerated due to the terrestrial atmosphere, burnt themselves out either completely or partially, due to friction with the air, leaving large trains of ash behind, which last for some hours in the sky before dissipation. Very bright meteors called fireballs or bolides appear at heights 90-135 km and usually end up by vaporisation at heights between 20-80 km; if they are able to come down to the lower denser layers of the atmosphere at 45-55 km a shock wave results and they are accompanied by sound phenomena of explosive type, resembling gunfire or even thunder claps, due to waves of compression and rarefaction, on the analogy of supersonic bangs caused by jet aeroplanes when they cross the sound barrier.

The great Arizona crater (diameter 1200 m, depth 175 m) is attributed to a meteorite which fell some 50,000 years ago and estimated to weigh 100,000 tons. The largest known meteorite crater in the world, known as the Chubb meteor, near Quebec (Canada), discovered only recently, is over two miles in diameter and 400 metres deep. In India the Dharamsala meteorite of 14 July 1860 is well known. Since over three-fourth of our globe is covered by the oceans, it goes without saying that several meteors do crash into the sea and although optical evidence is not available regarding these meteors, meteorites have been found on the ocean beds. It is significant and fortunate that up to now no meteor is known to have caused loss of human lives.

The atmospheric effects, especially the pressure waves of meteorite explosions of the world over, by instruments in India, does not appear to have been studied before. During the half century 1900-1950, a few outstanding meteorite falls have occurred, notably in the U.S.S.R., of which fortunately reliable information is available. The Alashan fireball of 12 December 1905, the great Siberian meteorite (Tunguska) of 30 June 1908, the Khonelyobka fireball of 1 March 1929, the Sikhote-Alin fireball of 12 February 1947 and the Kansas meteorite of 13 September 1947 are a few examples. The barographs in use in India at the time were not sensitive enough and they were obviously not designed for the study of such effects. Insensitive to such small effects of such distant meteorite phenomena, yet the barographs of the India met. Dep. stations have recorded the pressure waves in some cases. Descriptions of two meteors of the fireball type, which caused atmospheric pressure waves are given below.

2. Tunguska Meteorite (30 June 1908)

By far the most famous meteorite fall of the century is what is known as the Tunguska meteorite or popularly known as the great Siberian meteorite, which fell in the valley of Stony Tunguska River in Central Siberia at about 0700 hrs local time of 30 June 1908. Inhabitants of several villages in the vicinity of the fall area saw the great fireball and heard detonations like explosions. The Geophysical Observatory at Irkutsk reported a dazzling flare and a dark trail of cloud behind the fireball; thunderlike noises were also reported. The seismographs (Zöllner-Repsold) at the Irkutsk Observatory, closest to the fall area of the meteorite (950 km from the fall area), recorded an earthquake due to the meteorite; seismographs at Tashkent, Tiflis and Jena also recorded the earthquake. In 1927, U.S.S.R. Academy of Sciences sent a fact-finding mission headed by Leonid Kulik, a geologist, to the site of the fall. Trees were found fallen between 5-60 km in a radial way giving a fan-like appearance indicating that the winds had blown outward from the point of impact, while some others were standing erect shorn of their barks and branches. As far as information is available there was no loss of human life, but according to a report, 1000 reindeer perished. According to Kulik, the co-ordinates of the fall-area were Lat. 61°N and Long. 101° 18′E, which have been later determined more accurately as Lat. 60°·9 N and Long. 106°·9 E. Modern estimates based on energy calculations etc indicate that the Tunguska meteor must have weighed 10,000,000 tons. In a very recent paper, Ivanov has arrived at the conclusion that the time of explosion of the Tunguska meteorite is approximately $0^h\ 16 \cdot 9^m$ GMT. He opines that the explosions of the meteorite must have taken place at a height of about 6–9 km from the ground.

Fessenkov, Director of the Astrophysical Institute, Alma Ata (U.S.S.R.) is of the opinion that the Tunguska meteorite was really a small comet, with its dusty tail pointing away from the sun, which hit the earth with a great explosion; the dust tail spread in the atmosphere to a height of 80—500 km, reflected the sun's rays back to the earth which were responsible for the extension of twilight, mentioned later. Fessenkov says that the trajectory of the meteorite (or comet) was from south to north inclined to the horizon at 10° to 15°; its retrograde motion suggesting its cometary nature.

Other unusual phenomena attributed to the Tunguska meteor were the presence of silvery clouds very high up (obviously noctilucent clouds holding minute particles of meteoric material inside ice crystals) which reflected sunlight and extended the twilight in several parts of Europe and Asia, from the Yenesie to the Black Sea extending up to the Atlantic coast; in Britain twilight was extended up to 22 hrs, for a few days after the Tunguska meteor explosion. Solar halos were observed in England for several days. None of the U.S.S.R. expeditions which conducted extensive surveys in and near the fall-area could locate any meteoric crater or meteoric fragments (as were found near the great Arizona crater), a fact of great importance which lends further support to the cometary nature of the Tunguska event.

3. Sikhote—Alin Meteorite (12 Feb 1947)

The Sikhote-Alin meteorite of 12 February 1947 is perhaps the most studied meteorite in the world. It fell on the western spurs of the Sikhote—Alin mountain ridge at 10^h 38^m local time (00^h 38^m GMT) in broad daylight. The approximate co-ordinates of the fall area are Lat. 49°·2 N and Long. 134°·6 E, not far from Vladivostok on the eastern coast of Siberia and close to the town of Khabarovsk. Excellent recordings of pressure waves were made at the Tokyo Meteorological Observatory. According to reports, the brilliant fireball was brighter than the sun and it moved from north to south accompanied by loud explosions which could be heard for 400 km. Around an elliptical area running north-south of area about 2·5 square kilometres the trees had fallen or torn by the roots. The U.S.S.R. Academy of Sciences again sent a fact-finding mission which surveyed the place for 3 years from 1947 to 1950 and collected over 250 specimens with the aid of magnetometers, the biggest of which weighed 1745 kgm and the smallest 1/100th of a gram.

4. Discussion

Whipple has reproduced micro-barograms of six English stations relating to the Tunguska Meteorite explosion, obtained by the Shaw-Dine microbarograph, which is specially designed to record rapid changes of pressure some 20 times that of a mercurial barometer. The microbarographs and barographs in use at the Indian stations are, however, of different makes and different sensitivities. They are designed only to show the pressure change for the routine activities of the observatories and to aid the weather forecaster and not intended for 'capturing' the small fine oscillations due to meteor explosions. In fact the barographs in use in 1908 were far less sensitive than the ones in use now-a-days. Despite this drawback, it has been possible to recognise or isolate the pressure oscillations with some reasonable accuracy. The ordinary barograph records obtained in India pertaining to the nuclear explosions show waves of comparatively larger period, initially and the pressure waves associated with the meteoric explosions are similar although in some cases there is some evidence of finer very short period oscillations preceding the main kink itself. The kinks are, however, clearly recorded (*see* Fig. 1) and these are obviously due to the shock-waves.

The recording of the pressure waves of the Tunguska meteor (comet) in England had the following characteristics: waves of larger wave length (about 2 minutes) were the first to arrive at about 05^h 10^m GMT, which were followed by the short period oscillations recorded from 05^h 25^m to 05^h 32^m GMT. Whipple opines that the first part of the oscillations were produced by the passage of the meteor through the atmosphere and the sudden oscillations due to the impact with the ground. In India, owing to the limitations of the type of barographs in use, the short-period oscillations cannot be made out with any degree of certainty.

Tables 1 (a) and 1 (b) give particulars of pressure waves recorded at some Indian observatories together with values of velocity of the waves and Fig. 3 gives locations of some meteoric impacts and the isochrones for the Tunguska and Sikhote—Alin events.

The velocities of the pressure waves are slightly higher than those derived by Whipple. The pressure waves recorded in England were probably retarded by the powerful westerly winds and consequently, registered rather late on the barographs. The path of the waves registered in India must have mainly travelled through the stratosphere in SSW to SW direction at the high temperature level before coming down, the high mountains enroute having contributed as reflecting media, resulting in the comparatively higher velocity for the air waves.

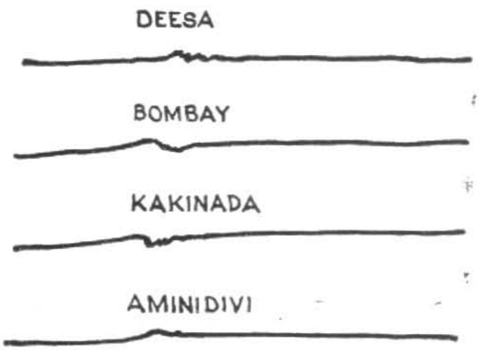

Fig. 1. Typical barograph records (enlarged) at some Indian stations showing kinks due to the pressure wave originating from the Tunguska Meteor (comet) explosion of 30 June 1908

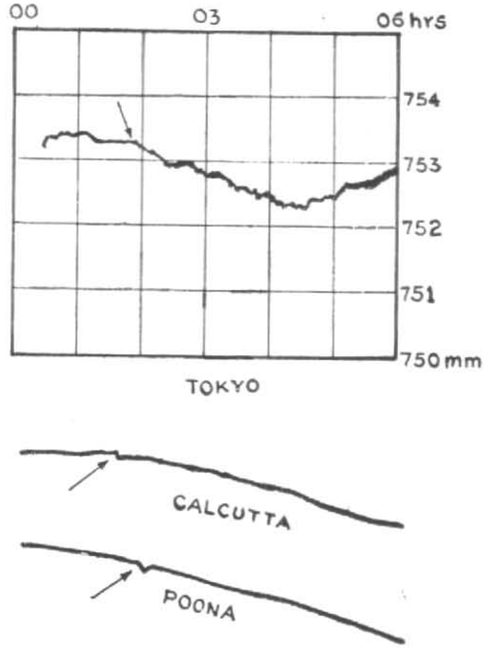

Fig. 2. Barograph record obtained at the Tokyo Meteorological Observatory showing the pressure wave due to the Sikhote—Alin meteor of 12 February 1947. Microbarograph records of Calcutta and Poona have also been reproduced. The kinks at the Indian stations are too small to be recognised.

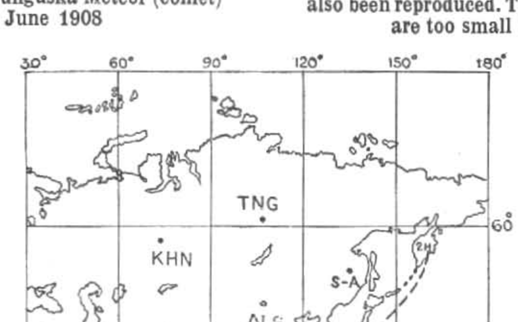

Fig. 3. Map showing the locations of the falls of 4 major fireballs during the present century

ALS—Alashan fireball of 12 December 1905
TNG—Tunguska meteor (comet) of 30 June 1908
KHN—Khonelyobka meteorite of 1 March 1929
S-A—Sikhote-Alin meteor of 12 February 1947
Isochrones for Tunguska (full lines) and Sikhote-Alin (broken lines) are indicated (timings in GMT)

TABLE 1(a)

The Tunguska Event of 30 June 1908

Geographical co-ordinates : Lat. 60°·9 N, Long. 106°·9 E

Station	Arc distance from place of impact of meteor (comet) (km)	Time at which pressure wave was recorded (GMT)	Velocity of pressure wave (metres/sec)
Burdwan	4335	0358	326·9
Allahabad	4335	0400	324·0
Balasore	4555	0407	330·1
Cuttack	4780	0433	311·2
Deesa	4945	0447	305·2
Kakinada	5220	0451	317·5
Bombay	5445	0514	305·6
Coimbatore	6110	0540	315·3
Aminidivi	6335	0559	308·7

Average velocity of pressure wave=316·1 metres/sec

TABLE 1(b)

The Sikhote—Alin Meteor of 12 February 1947

Geographical co-ordinates : Lat. 49°·2 N, Long. 134°·6 E

Station	Arc distance from place of impact of meteor (km)	Time at which pressure wave was recorded (GMT)	Velocity of pressure wave (metres/sec)
Calcutta	5000	0450	330·7
Poona	6390	0610	320·8
Tokyo (Japan)	1555	0155	336·6

NOTE—The timings of the recording of the pressure waves have been estimated as correctly as practicable; but due to limitations of the instrument and the recording, a deviation of ±5 minutes is possible. The displacement in the barograph traces were small, all of the order of 0·01 to 0·02 of an inch of pressure.

5. Conclusion

Meteor explosions of great magnitude have been detected even by ordinary barographs in India, although sensitive barographs of the Shaw-Dines or other modern type are preferred for clear recordings. So far as ordinary barographs go, the pressure recording is similar to that of nuclear explosions in the megaton range. Since the kinks in the pressure records associated with the Tunguska event (1908) have been recorded by even the insensitive barographs of the time in far off places like India, the author substantiates that the event is undoubtedly a very major one. The instrumental recordings, coupled with the facts that no sizeable meteors or craters were found at the scene and the presence of solar halos during day-time and the extension of twilight upto near midnight in England and other places in Europe, observed for a few days after the event, evidently due to the reflection of the sunlight from the particles of the tail of the comet spread in the higher regions of the atmosphere (the light from the sky at midnight was so strong that even books with small print could be read by it), all lend support to Fessenkov's hypothesis that the Tunguska event is due to a comet and not a meteor. The absence of a magnetic storm or disturbance on 30 June 1908, and the failure to locate the spectral lines characteristic of the Aurora, rule out that the light was auroral. The Sikhote-Alin event (1947) did not result in the extension of twilight which places the Tunguska event in a class by itself. When the records of sensitive barographs of the Shaw-Dines type of great sensitivity installed at some selected stations, for the detection of meteor explosions, become available these would be helpful in the study of pressure waves due to meteor explosions.

6. Acknowledgements

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