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THE AVALANCHES OF DECEMBER 1966 IN WESTERN T'IEN-SHAN, CHINA

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Abstract. The exceptional avalanches of December 1966 in the basins of the Gunes and Kashi Rivers caused much damage and blocked the highway for several months. The general avalanche conditions in this area and the exceptional weather which caused the exceptional avalanches are described.

Résumé. *Les avalanches de décembre 1966 dans l'Ouest du T'ien-shan, Chine.* Les avalanches exceptionnelles de décembre 1966 dans les bassins des rivières Gunes et Kashi ont provoqué de nombreux dommages et coupé les routes principales pendant plusieurs mois. On décrit les conditions générales nivologiques dans cette région et les circonstances météorologiques exceptionnelles qui ont provoqué ces avalanches exceptionnelles.

Zusammenfassung. *Die Lawinen vom Dezember 1966 in West-Tienschan, China.* Die aussergewöhnliche Lawinentätigkeit vom Dezember 1966 in den Tälern des Gunes- und Kashi-Flusses verursachte grossen Schaden und sperrte die Strasse für einige Monate. Die allgemeinen Lawinenverhältnisse in diesem Gebiet und die aussergewöhnlichen Wetterbedingungen, die zu der Häufung von Lawinen führten, werden beschrieben.

Full-depth avalanches occurred on 20–23 December 1966 in the basin of the Gunes and Kashi Rivers, two adjoining distributaries of the Ili River in western T'ien-shan, China.

Investigations and data showed that, besides the avalanches which happened in December 1966, there had probably been avalanches in the winter of 1927, and in the spring of 1934, 1960, and 1964. The local herdsmen said that the scale of the avalanches which happened in December 1966 was the largest and most serious. At that time, the highway through this region had just been opened to traffic. Many people who had just come here were hit by the avalanches. The local herdsmen and forestry workers were hit, too. The T'ien-shan Avalanche Station (1 776 m a.s.l.) was set up in the valley of the Gunes River in 1967. Since then the station has been carrying out researches on avalanches and their prevention.

I. Disasters caused by avalanches

The avalanches in 1966 spread over the vast areas in the basin of the Gunes and Kashi Rivers. We made observations in key districts after the avalanches had happened. The highway through the Gunes valley was completely blocked. In the canyon section (1 500–1 900 m a.s.l.), a section of the highway was buried by avalanche deposits. A chain of avalanche deposits could be seen on the roadbed. Their heights were different, the highest reaching 12 m. The total amount of avalanche deposits was estimated at 440 000 m³. These snow deposits only melted away in April or May of the next year. Throughout this period, highway traffic was completely interrupted. The roadbed in some places was destroyed by the avalanche. The avalanches also damaged the forests on both slopes of Gunes. For example, a chute on the sunny slope of Gunes had a snow catchment area of 95 000 m². At that time, snow released from the mountain top (2 000 m a.s.l.), passed through the slope, crossed the highway, and the river (1 500 m a.s.l.), and reached the opposite bank of the valley. The volume totalled 20 000 m³. Owing to the action of air blast and avalanche, about 5 000 m² of forest in the lower part of the shady slope was destroyed. Many trees with strange shapes were formed by the avalanche. Strong avalanches broke the roadside wires and poles. More than 50 people were injured or killed, thousands of livestock were buried, and scores of houses were damaged.

II. Conditions for the formation of avalanches

Both the Gunes River and the Kashi River are in valleys running from east to west. They flow into the Ili Basin which is surrounded by mountains on three sides and opens to the west. The mountains on the northern and southern sides are higher than those on the eastern side. Furthermore the Ili Basin is wide in the west and narrow in the east. It dips to the west (Hsin-chiang Tsung-he K'ao-ch'a-tui,

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1978). This topographic situation is favourable to the invasion of weather systems in the westerly belt. When the weather system is moving eastward, precipitation is increased due to orographic condensation. The basin of the Gunes and Kashi Rivers is the region which has the most precipitation in T'ien-shan. The annual mean precipitation at the T'ien-shan Avalanche Station is 913.4 mm, and the maximum 1 139.7 mm. In winter, the precipitation is 300 mm. The stable snow-cover period lasts for 130 d or so, with a maximum depth of 50–80 cm.

The Gunes and Kashi River basins are 1 500–3 000 m a.s.l. The depths of down-cutting are 200–300 m in the front range district and 800–900 m in the divide district. The valley was obviously eroded and formed numerous canyons. The inclination of the slope is generally 30°–40°. Due to displacement deformation and run-off dissection, the planation surfaces at the elevation of 2 000–3 000 m in these districts are quite broken (Hsin-chiang Tsung-he K'ao-ch'a-tui, 1978). The erosion, nivation, and landslip are comparatively strong. In the avalanche-stricken section in the main valley of the Gunes River the mean density of avalanche formation area (Zalikhanov, 1975) on the sunny slope is 3/km. The avalanche starting zones are not particularly large and the avalanche paths are short (Chung-kuo K'e-hsüeh-yüan Lan-chou Ping-ch'uan Tung-t'u Sha-mo Yen-chiu-so, 1976). Slopes with weak dissection are widely distributed. These slopes are 200–500 m high above the valley floor (Hsin-chiang Tsung-he K'ao-ch'a-tui, 1978; Losev, 1966). Furthermore, vegetation luxuriates in these districts. The sunny slope grows luxuriant grass. The shady slope at an elevation of 1 500–2 800 m is covered with dense picea. The above-mentioned orographic, climatic, and topographical conditions are favourable to the formation of avalanches. The results of our research indicate that these districts have the highest avalanche frequency in the intermediate zone of T'ien-shan.

According to the weather reports, on 7–18 December 1966, there were four incursions of depressions into the basin of the Gunes and Kashi Rivers. The dates of the incursions were 7, 9–10, 12–13, and 16–18 December respectively. The first three storms brought about snow-fall in the main, especially the third, but the decrease of air temperature was not obvious. On 16–18 December cold air from the Arctic Ocean flowed southward and brought cold weather. Snow-fall was heavy, and air temperature dropped sharply. Because cold air flowed southward all the time, snow-fall and low temperatures lasted for a comparatively long time.

III. The cause of the avalanches

The combination of favourable meteorological and climatic conditions in these districts brought about the occurrence of the avalanches (Zalikhanov, 1975). First of all, owing to the frequent cyclonic invasion, the above districts were affected by storms in ten successive days and the depressions became stronger and stronger. Therefore, foggy and snowy weather appeared in the above districts. This kind of weather was favourable to the continual increase of snow depth on the slopes. The fourth system brought a cold wave with heavy snow-fall being followed by low temperatures. At that time, the maximum temperature in the basin of the Gunes and Kashi Rivers was lower than −10.0°C. These continuous low temperatures impeded the melting of snow cover on the slope and thus snow depth rapidly increased.

Secondly, the paths of the four storms bearing precipitation were quite coincident. Their precipitation centres were all in the intermediate zone of the basin of the Gunes and Kashi Rivers. According to the calculation of related data at that time, the total precipitation of the four storms was more than 100 mm at the T'ien-shan Avalanche Station. The snow depth on the slope was 120–150 cm.

Thirdly, before 15 December the air temperature in the basin of the Gunes and Kashi Rivers was generally about 0°C. The cold conditions arrived on 16 December. The air temperature went down sharply and remained for a comparatively long time. But on 20 December cold air moved eastward quickly. The basin of the Gunes and Kashi Rivers was controlled by a warm advection air-mass. Air temperature went up rapidly. On 22 December the air temperature rose again to about 0°C and thus snow-melting weather appeared, which was closely related to the warm advection air-mass. The avalanches began on 20 December 1966 and became more frequent on 22 December. Evidently, the occurrence of the avalanches coincided with the time when the snow melt came.

In early winter, due to the fact that snow cover suffered from repeated melting and freezing, an ice crust formed on its surface. This ice crust was the main gliding surface for the avalanches.

Thus it can be seen that the avalanches were closely related to the rapid increase of snow-cover depth and subsequent snow-melting weather (Troshkina, 1977).

IV. Features of the avalanches

The avalanches which happened in the basin of the Gunes and Kashi Rivers in December 1966 were of the full-depth kind. This kind is more typical in valley districts. Snow-storm avalanches are not of great significance in valley districts. In the divide district between the basin of the Gunes and Kashi Rivers, snow-storms are frequent in winter. According to our observations, the maximum wind velocity in the divide district can reach 30.0 m/s. Snow-storms provide a large amount of snow in the divide district and snow is transferred from windward slopes to leeward slopes and forms very thick snow cornices. At that time, some snow-storm avalanches happened in the divide district of the basin of the Gunes and Kashi Rivers.

The shady slopes in the basin of the Gunes and Kashi Rivers are covered with luxuriant forests. At that time, with the exception of some chutes with no forests, no avalanches happened on the great majority of shady slopes. On the contrary, there are no forests on the sunny slopes. In addition, the withered grass, which covers the slope, is comparatively smooth. These factors are favourable to the occurrence of avalanches. Therefore, as compared with the shady slopes, avalanches on the sunny slopes are more frequent, larger in scale, and also more disastrous. And so, in the basin of the Gunes and Kashi Rivers, the avalanche conditions, including avalanche activity, disaster, and frequency, are related to the exposure of the slope and the condition of the ground surface.

To sum up, the avalanches in the basin of the Gunes and Kashi Rivers are mainly channelled avalanches, secondarily unconfined avalanches; airborne powder avalanches are rare. The magnitude of channelled avalanches varies generally from several thousand to nearly ten thousand cubic metres. The path of channelled avalanche is generally 400–800 m, with a minority of 1 000 m. Most of the channelled avalanches can reach the piedmont and the river bed. A few of them can reach the piedmont of the opposite bank of the valley. In this region, an unconfined avalanche on weakly dissected slopes is comparatively typical, with a running distance of 200–500 m. Avalanche debris accumulates at the piedmont in mounds with a height of 2–4 m. There are only a few airborne powder avalanches. The avalanche which destroyed the forests was of the airborne powder type.

The highest fracture point of the avalanches appeared in the divide district (3 000 m a.s.l.). The lowest elevation of the avalanche deposits in the valley was 1 500 m a.s.l. There were 278 avalanche deposits in the avalanche-stricken district of the main valley of the Gunes River. The total amount of the avalanche deposits was 1.2×10^6 m^3, accounting for about 20% of the slope snow in this district.

The calculation of avalanche frequency shows that the repeat period of the avalanches is more than 50 years.

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