tion and probable dessication and deforestration to happen during Subboreal (Lusatia culture of the Late Bronze Age) some 3 ka BP.

4. The Late Glacial represents the most important erosional and downcutting event of the last 20 thousand years.
5. The future direction of research will lead in next two years to field research in Hradèany area close to Mimoò and probably in Labské pískovce area. Then the synthesis of the broad interdisciplinary research is planned to be published as English monograph.
6. The sandstone rockshelters of Northern Bohemia yielded after a decade of the intense research more facts about Mesolithic life than a century of previous studies, because of the accompanying fossil relicts that became preserved in dry, calcareous environment. We believe that sandstone rockshelters may represent such a unique record of prehistoric cultures (e.g. hunting activities of Neolithic population) that we plan to stop our research in order not to destroy the sites for future more detailed excavations.
7. The next plans will concentrate on the protection of the sites in cooperation with the offices of landscape protected areas and ministry of environment.

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The Influence of Climate on the České Středohoří Mts. Slope Deformations - Data Analysis since the 18th Century

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ABSTRACT. Data from localities showing the highest occurrence of catastrophic slope deformations have been summarised in frames of the České Středohoří Mts. slope stability failure research. Even though the oldest data come from 1531, a serious data sequence before the middle of the 18th century are not available. Periods when the slope deformations occurred were correlated with climatic variations. For the period preceding established climatic observations, an assumed course of climate has been derived studying data scattered in historical files.

KEY WORDS: landslides, debris flows, frequency of slope movements, precipitation, floods.

Introduction

Making investigation into the slope deformations in the area of the České Středohoří Mts. within a grant project of the Grant Agency of the Czech Republic, Reg. No. 205/98/1551, data about sliding phenomena in the period of the last 300 years were collected. The data were correlated with climatic conditions, with an aim to evaluate the influence of individual climatic factors, and to improve slope deformation prognosis.

Methods

Database of landslide phenomena

Basic data have been taken from the Historical Catalogue of landslide phenomena, published by Špůrek (1972). He evaluated usable data about slope movements till 1970, showing the character of sliding, flow, as well as rockfall, and excerpted both published and archived hand written data including information from the newspaper cutting service. Data from Europe are prevailing, while other continents have only limited coverage. Besides, register of landslide phenomena in Europe for the period of 1970–1987 has also been available (Špůrek 1989). Last data from the Czech Republic territory have been obtained through excerptions from the current records in the register of slope deformations of Geofond CR, and also through the cooperation with public administrative institutions. Personal observations of the authors have been used, as well. Total number of 160 dated phenomena have been used for the area of the České Středohoří Mts. Even marginal zones of the České Středohoří Mts. are included into the evaluated territory, including insulated volcanic bodies permeating sediments of the Bohemian Cretaceous Plateau (e.g. Hazmburk, Raná, etc.).

The oldest data about landslides from the localities Radobýl and Zahořany in Litoměřice district come from April and May 1531. More numerous reports about landslides has been recorded as late as since the middle of the 18th century, and it was particularly the year 1770 that was covered. It was the landslide of flow type, the frontal part of which blocked partially the Labe River bed on 5th January 1770 in the Veselí Village (Ústí nad Labem District) which is one of the best known from that period. Towards the end of the 19th century and in the 20th century the record frequency was increasing continually, owing to the systematic recording of landslide areas for the territory of former Czechoslovakia in the years 1962 and 1963. Moreover, it is a register of landslides which is available at Geofond archives.

The number of records from different periods does not depend only on actual occurrence of catastrophic events, but to a large extent it is affected by a current social and political situation. In the catalogue of Špůrek (1972), e.g., the number of data from the years 1897–1900 dominate. These were the years when a part of the Klapý Village on slopes below Hazmburk Castle was destroyed. This event had a good coverage and a good response in Austro-Hungarian governmental circles of that time. The number of reported cases of that period was obviously exaggerated comparing with other catastrophic situations. Contrary to that, it was the period of the World War II where the coverage of landsliding was insufficient as indicated by some German hand written sources showing that particularly in the years 1939 and 1941 there was an enormous increase of landslides in the evaluated territory. Regarding that, the evaluation of landslide phenomena frequency cannot depend on recorded numbers of events only. It is the following simplified characteristic of individual periods which can express it better: period of individual landslides, period of increased frequency of landslides, period of avalanche-like landsliding.

Dating of past slides can be in a limited extent investigated using methods of dendrochronology. These are used in studies of annual ring anomalies of trees struck by landslides. In the locality Čeřeniště, north of Litoměřice, that was struck by deep gravitation movements in neovolcanites, several phases of reactivating of movements were found (Fantucci et al., in press). Although these investigations were preliminary, the results in most cases correspond with periods of increased frequency of landsliding in Bohemia.

Precipitation and temperature data

Data from the Louny Observatory, situated near the southern edge of the České Středohoří Mts., were used for the evaluation of precipitation. Here, the precipitation recording has been carried out since 1877. Fig. 1 shows graphically the course of annual precipitation with regard to the percentage difference between real precipitation totals and long-term precipitation averages. For the period after 1700 precipitation conditions in Bohemia territory can be derived from the work of Brázdil (1990). He analysed written narrative documents presenting information about weather or events dependent on weather like dry periods, rains, snowing, floods and crop failure. To verify basic climatic trends starting from the year 1804 it was possible to use records from Prague Clementinum Observatory. Results of analysis of historical sources for Bohemia were also provided by Svoboda (1998). He defined approximately periods of increasing and also decreasing precipitation activity, as well as periods with distinctive changes in temperature, notably periods of cooling. Pažourek (1995) evaluated data about the biggest floods on the Labe River in Děčín for the period before the instrumental monitoring was set up. Data published by Hydrometeorological Institute (Horský, 1975) were available for the period of 1851–1970. The graph of Fig. 2 shows 20 years flood. Data about flow culmination from ČHMÚ in Benešov nad Ploučnicí were also used, as well as reports about other floods on some of the Labe River tributaries linked to increased landsliding.

Data analysis

Fig. 2 shows the relation between landslide activity in the territory of the České Středohoří Mts. and individual climatic factors in the last 300 years.

It is possible to compare all three typical periods of landsliding: individual, increased and avalanche-like, with precipitation and temperature variation, as well as with the Vltava

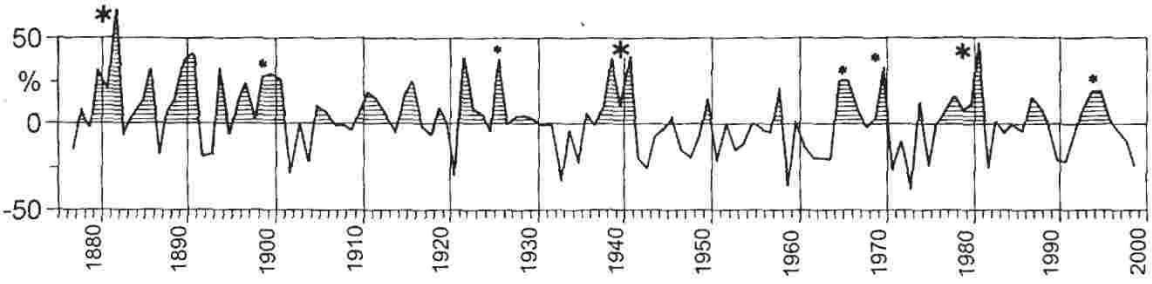

Fig. 1. Yearly precipitation totals as observed at the Louny Observatory. Periods of increased activation of landsliding are marked with asterisks.

River flows in Prague and with the biggest floods on the Labe River in Děčín and on some of the Labe River tributaries.

Medium deep and deep landslides are among the widely spread landslide movements in the area of the České Středohoří Mts. In the cover formations less extensive shallow slides, earth and debris flows occur, too. However, the data about them are mostly missing. There are also deep block movements on plastic underlying beds that are typical for the České Středohoří Mts. At present, these are natural conditions permanently stabilised. The reactivating of block movements cannot be proved in the evaluated period of 300 years. In the rigid volcanic rocks of steep slopes, there occur local rock falls and minor falls, but dating, with several exceptions, is missing.

Medium deep and deep landslides

Fig. 1 was prepared to present the influence of precipitation on the development of medium deep and deep landslides. For the Louny Observatory there are percentage differences noted between real precipitation totals and long-term precipitation averages in the period 1877–1999. The peaks of the curve coincide with culmination of landslide calamities. Periods of increased up to avalanche-like occurrence of landsliding, often evident even in other European regions, are marked with a bigger asterisk, while smaller asterisk marks a period of an increased landslide occurrence phenomena usually of local significance only.

Long-term precipitation balance and water saturation of rock is important for the development of medium deep landslides. To activate movements a certain critical level of water-bearing must usually be reached. In extreme meteorological situations there can be reached a maximum water saturation of slopes in a wide region or in several regions at the same time. Slopes are then hit by an avalanche-like landsliding. In the claystones of Bohemian Cretaceous Plateau such a situation develops mostly after two or three years period of abnormal precipitation (Rybář, 1999). In the volcanic rocks of the České Středohoří Mts. such a situation can develop even after shorter period of increased precipitation.

The last avalanche-like landsliding in the northern half of Bohemia developed in winter 1981/1982. Analogical latitudes of Western Europe were hit at the same time. Similarity of extreme precipitation and avalanche-like landslides, earth and debris flows at the western American coast occurring at the same time, is striking. The climate there is dependent on El Niño and La Niña phenomena, having their origin in eastern tropical part of the Pacific. However, the climate in Europe is responding, too.

A comparable anomaly in long-term precipitation balance linked with the top frequency of landsliding in Bohemia occurred in the years 1939–1941. In addition to that, during this period the effect of excessive precipitation was strengthened by decreased average temperatures. Owing to the lower evaporation a bigger part of the precipitation functioned as effective precipitation, i.e. precipitation able of infiltration (Novotný and Rybář, 1996). Another significant period were the years 1882–1883, with their landslide calamities in North Bohemia. These were reported also from southern Germany and Austria.

A number of other peaks of the curve in Fig. 1 correlate obviously with deformations of catastrophic extent in one isolated area only. One can provide the example of Klapý Village at the slope toe of Hazmburk Castle located in the affected territory of central/northern part of Bohemia which suffered a disaster of destruction in the years 1897–1900. In the period of 1995–1996 there was an increased landslide occurrence in almost the same part of Bohemia, as well. An increased landsliding also developed in the Labe River valley section of the České Středohoří Mts. in the years 1914 and 1926. In June 1926 northeast of Bohemia was hit, and a bigger part of Dneboh village on the slopes of Mužský Hill was destroyed. Many disastrous situations developed also in the years 1965–1966 a and partly in 1970.

On the curve of precipitation in Fig. 1 one can follow some peaks not linked with any proved increased landsliding. It is the case of the years 1890–1891, 1894 and 1922. All these cases of enormous annual precipitation totals were preceded by considerably dry periods. In case of using the method of three year scattered totals used for evaluating of precipitation balance in clayey sediments of Bohemian Cretaceous Plateau (Rybář, 1999), such peaks of the curve would become significantly lower.

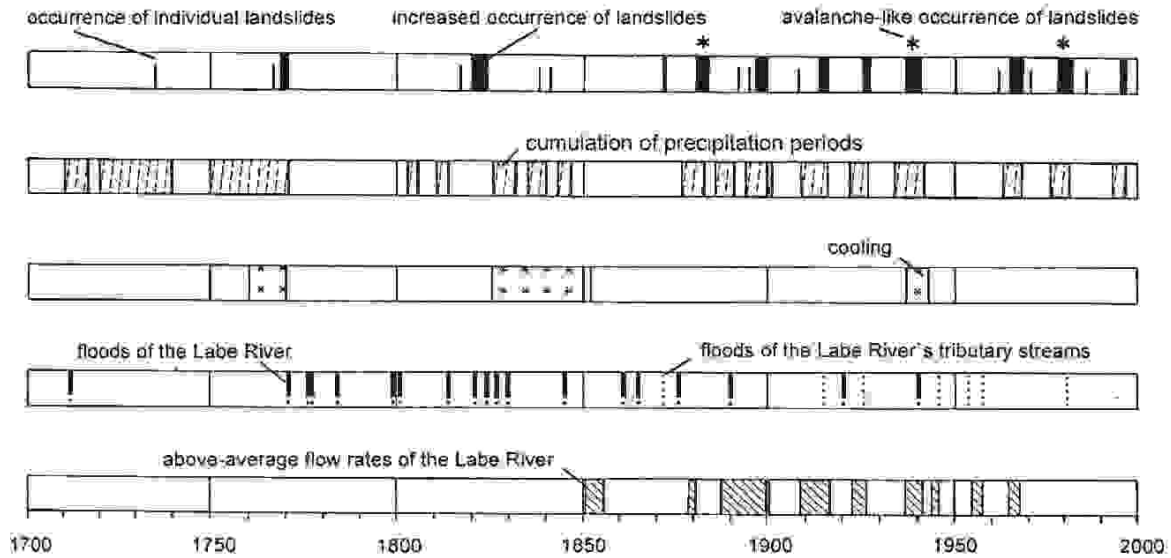

Fig. 2. Evaluation of landsliding in the České Středohoří Mts. showing correlation with selected climatic factors.

Fig. 2 covering the early period till the year 1876, shows an increased landsliding in 1770 (see also chapter 2.1). This period also followed a period of increased precipitation. A similar situation appeared in 1823 and 1824 (Říp Hill landslide).

Shallow landslides, earth and debris flows

More direct relation between precipitation, temperature changes, and reactivating of movements can be met in case of slope movements on cover formations of lower thickness, possibly only on their superficial parts. The process of sliding is being transformed into flow. In most cases a long-term saturation of the massif is not a necessary condition but a short-term intensive soaking of the slope surface in a period of intensive rain falls or spring thaw, could be sufficient. These are the climatic situations when flood occur on major rivers, and notably on their minor tributaries. Water streams undercut banks, erosion gullies originate with frequent minor slides and flows. Damage caused to the properties of local inhabitants, and casualties caused by such floods overshadow other losses caused by parallel deformations of smaller size on slopes. Therefore, records about slope deformations that occurred in connection with floods used to be exceptional. There is one exception connected with the tragical event of May 1872 in Bohemia, notably in the region west of Prague (Skrejšovský, 1872). Extreme torrential rains of that time resulted in about 320 casualties in the drainage area of the rivers Berounka and Blšanka and in lower river sections of Ohře and Vltava. Other deep landslides occurred in May 1872, although, the period was characterised by a precipitation balance considerably lower than average. One of the largest landslides was 800m wide, and completely destroyed the railroad Prague - Chomutov on the left bank of the Blšanka River near Měcholupy Village under the basaltic hill of Chlum. Debris flows originate during intensive precipitation on minor tributaries in the Labe River gorge. These carry a considerably large amount of sediments to the valley. The sediments come usually from landslide deposits on the upper section of the drainage area. It was by the end of the 19th century when an increased number of debris flows endangered traffic of the railroad, as well as river transport. The frontal parts of the debris flows narrowed the river bed considerably. A series of improving measures to cut down problems with dangerous currents were introduced at the beginning of the 20th century, As an example is the stream of Čeřeniště which drains one of the most extensive landslides of the České Středohoří Mts. was partially regulated with reinforcement of its bed, a series of stone stilling baffles and retaining walls was constructed, and even the area of the landslide was partially drainaged. The effectiveness of such measures was proved as early as in August 11, 1925, when intensive rains resulted in local floods there. Some of the regulation measures were damaged but the frequent damages in the flood plain of the Labe River known in the past were stopped.

Conclusions

One of the aims of engineering geological research into slope movements is improving the prognosis. We can differentiate prognosis into territory, prognosis into mechanics, into size and time prognosis. Under the territorial conditions of the Czech Republic the first two types of prognosis are relatively easy. One can use the data base about landslides registered in Geofond of the Czech Republic. Experience shows that about 90% of new slide movements originate in places where stability was disturbed in the past. Contrary to that, time prognosis, especially long-term prognosis, is very difficult. There are reports about numerous attempts to define general cycles in landslide activity. These attempts have not been too successful, like prognosis into long-term course of climate which is decisive in landsliding. A short-term prognosis can be more successful when studying individual cases in detail, with monitoring results available. It is possible to define thresholds of the precipitation totals, of the water saturation, and even of the deformation. One can come to warning criteria which in some cases may prevent catastrophic events.

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