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Dating of earthquakes: tree ring responses to the catastrophic earthquake of 1887 in Alma-Ata, Kazakhstan

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A tree ring study of *Picea schrenkiana* Fisch. *et* Mey. growing on the northern slopes of the Zaileeskii Alatau mountain ranges near the epicentre of the 1887 earthquake was carried out to evaluate the effect of strong earthquakes on tree growth patterns. Tree growth was found to be severely reduced following the earthquake, generally for a period of three to four years, but in certain cases growth suppression lasted for up to 15 years. The long-term growth suppression is attributed to the tilting of trees as a result of the earthquake. Such studies in earthquake-prone zones can be of value in identifying and dating prehistoric earthquake events.

KEY WORDS: Alma-Ata, earthquakes, tree rings, growth suppression.

STRONG EARTHQUAKES OCCUR in tectonically active areas. In Central Asia such activity is common in the Tien-Shan and Pamir mountains (Kurskev, 1990). The loss of life and material damage caused by catastrophic earthquakes accentuates the need to understand their frequency and occurrence, and the locations where such events are most likely to occur, so that the human impact of such disasters can be minimized. Unfortunately, the understanding of the recurrence of such events is greatly hampered by the limited length of seismic records. In northern Tien-Shan earthquakes of more than 5–6 magnitude have been fully reported only since 1865 (Nurmagambetov and Sidikov, 1984). Proxy sources such as historical records, carbon 14 dating of sedimentary sequences and dating of faults from an estimation of scarp erosion rates, have been used in dating earthquakes, but such methods lack precision.

Dendrochronology, however, offers the potential for dating prehistoric events to the actual year of their occurrence. Strong seismic shocks cause intensive physical damage to trees such as the severing of roots, tilting and sometimes their complete destruction. Trees surviving such shocks record the event in their annual growth rings with features such as narrow rings, and increased proportions of reaction wood. Earlier studies that have led to the dating of earthquakes to the year of their occurrence include Page (1970); LaMarche and Wallace (1972); Meisling and Sieh (1980); Ruzhich *et al.* (1982); Jacoby and Ulan (1984); Kaiser and Kaiser-Bernhard (1987); Sheppard and Jacoby (1987); and Jacoby *et al.* (1988). In some cases it has been noted that the event could be dated to the accuracy of months if it occurred during the growing period (Shroder and Butler, 1987).

The present study reports on the tree ring response in *Picea schrenkiana* to the known catastrophic earthquake of 1887 in Alma-Ata, Kazakhstan. The trees were growing close to the epicentre of the event.

Study area

Alma-Ata experiences short cool summers (mean July temperature of 15°C) and very cold winters (mean January temperature of −9.5°C). Mean annual precipitation is 750 millimetres (Utesheva, 1959). Earthquakes occur frequently: weaker earthquakes up to a magnitude of 5 are felt several times a year (Kondarskaya and Shebalin, 1977); and in more recent years the town of Alma-Ata has suffered two great earthquakes, in 1887 and 1911, of 7.5 and 8.3 magnitude respectively. The epicentre of the 1887 earthquake was about 10 kilometres south of the town (43.1°N and 76.8°E), whilst the epicentre of the 1911 earthquake was 30 kilometres south of the town (42.9°N and 76.9°E). The present study is based on the tree ring evidence from near the epicentre of the 1887 event. This catastrophic earthquake occurred on 9 June (28 May according

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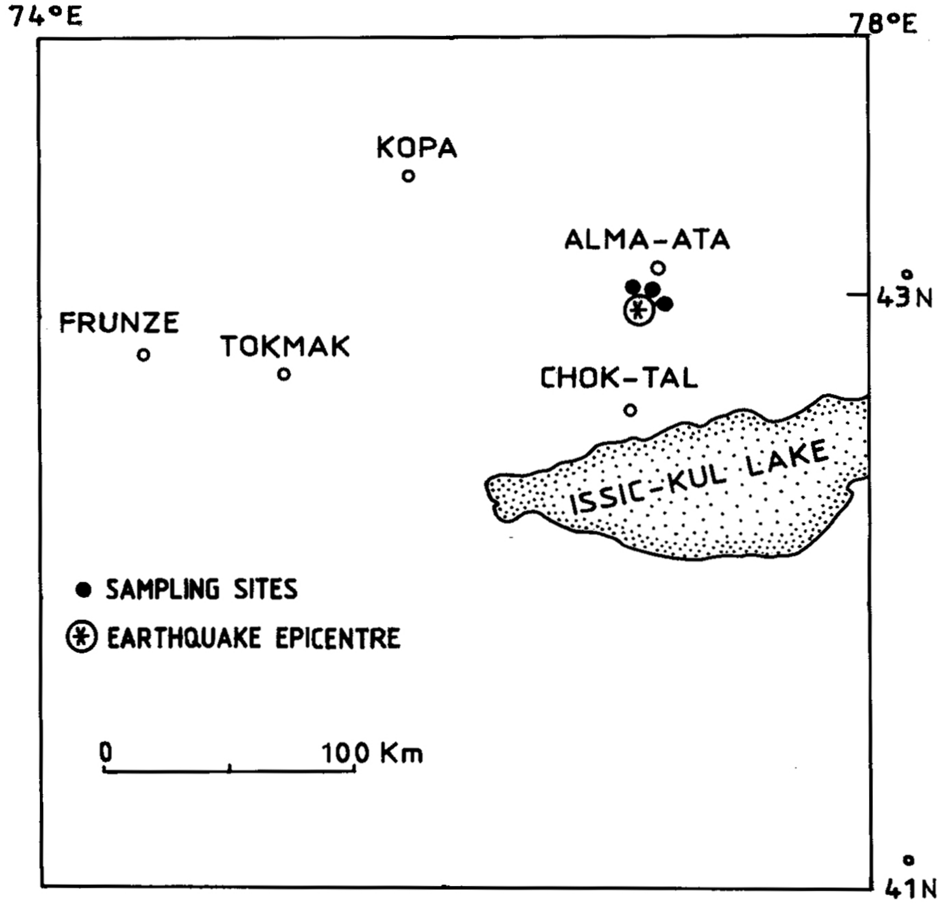

Fig. 1. The location of sample sites in the Alma-Ata area

to the old Russian calendar) at 04.35 a.m. local time. The effect of the earthquake was observed over a total area of 175 square kilometres. The damage caused as a result of the earthquake can be imagined from the newspaper reports such as 'the death of the town', 'thousands of people homeless', 'desert in place of blooming valleys'. The shaking caused by this earthquake was so strong that it was even difficult for people to balance on their feet (Musketov, 1890). In the town of Alma-Ata most of the buildings, including the ancient ones, were destroyed and in some cases only wooden frames were left. The strongest effect of the earthquake was noted on the northern slopes of Zaileeskii Alatau, where many valleys were blocked by huge landslides.

Methodology

The use of dendrochronology for the dating of earthquake events concentrates on the effects on tree growth. As there are many local factors that can also affect the pattern of tree growth, sampling sites should be selected carefully so that altered growth patterns can be clearly attributed to an earthquake event. Thus the authors made a reconnaissance survey of the area and vegetation with the aim of maximizing the earthquake signal reflected in the trees. Three forest stands of *Picea schrenkiana* Fisch. *et* Mey. growing near the epicentre of the 1887 earthquake were chosen for the present study (Fig.1). Ten trees from each stand were selected for tree core sampling. As the tree rings showed a good pattern and trees were not very old, one tree core from each tree proved to be sufficient for dating. Trees were cored at breast height on their upslope side. The upslope side was chosen for coring because in gymnosperms, in the event of any tilting, the rings on the upslope side show most growth suppression (Westing, 1968).

For event-response studies it is of prime importance to establish the calendar dates for the consecutive annual tree rings. The conventional procedure of cross-dating is usually adopted for this purpose. In principle, it refers to the establishment of general year-to-year synchronity between variations in the tree ring characteristics of different trees. Cross-dating also involves detecting and correcting for any lack of synchronity as a result of missing or false rings and simple observational or

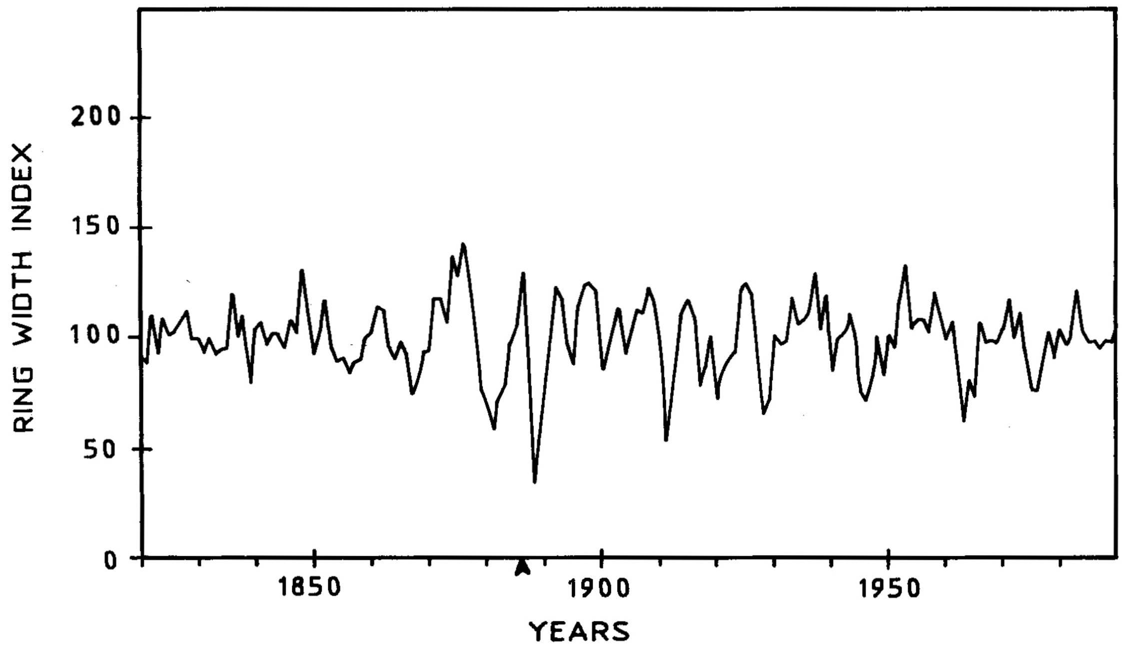

Fig. 2. Mean ring width chronology of Picea schrenkiana 1820–1990 AD

counting errors. Successful cross-dating ensures that all ring features are placed properly in the correct time sequence. In the present study tree core samples were cross-dated by collating the ring-width pattern of different trees following the usual skeleton plot method (Stokes and Smiley, 1968). The ring width patterns of dated individual trees were examined for evidence of simultaneous disturbance. This was followed by intrasite and intersite comparison of many individual trees to ensure that the evidence of disturbance was not unique to any one tree or site. Ring widths of cross-dated samples were measured to 0.01 millimetre accuracy and converted into ring width indices following the procedure of Bitvinskas (1974). The mean chronology extending from 1820–1990 AD was prepared from the average of 15 individual tree ring series (Fig.2). The trees which showed prolonged growth suppression (i.e more than five years) were not taken into account in establishing the chronology. Seven such trees (three from the first and two each from the second and third sites) showed growth suppression extending up to 15 years. The ring width indices of two of the trees showing long-term growth suppression are shown in Figure 3a and 3b.

Evidence of the earthquake in tree rings

The study revealed two types of ring pattern which could be attributed to the earthquake event of 1887. The majority of trees showed reduced growth, represented by narrow growth rings, following the year of the earthquake. The growth rings of 1887 were not found to be significantly narrow except in a few cases. In contrast the late wood of 1887 was found to be narrow in many cases. The absence of a distinctly narrow growth ring for 1887, despite the fact that the trees experienced physical damage in the growing season, suggests that the xylem increment of trees largely depends on the previous year's stored resources. Sharp growth reductions were, however, noted in 1888 and reductions were seen to continue for three to four years after which trees resumed normal growth. Such growth reductions could result from tearing of the roots, which would greatly reduce the nutrient uptake of the trees. The reduced tree growth as the result of such damage recovers only slowly, as new roots are formed to rebalance the root-shoot ratio.

The second prominent and synchronous pattern in ring widths was prolonged growth suppression, beginning from 1888. This suppression was found to continue for as long as 15 years in some cases. This type of suppression is attributed to the tilting of trees caused by the intense shaking, and possibly slope failure, during the earthquake. Trees on mountainous slopes are particularly prone to tilting, which is reflected in the production of eccentric growth rings for several years, depending on the extent of tilting, until the stem is growing vertically again. As in gymnosperms, growth rings on the upper side of the stem opposite the lean were usually found to be narrow in comparison with the contemporary rings on the opposite side; this suppressed growth seems to be a sensitive indicator of the physical forces causing the tilting of trees. The

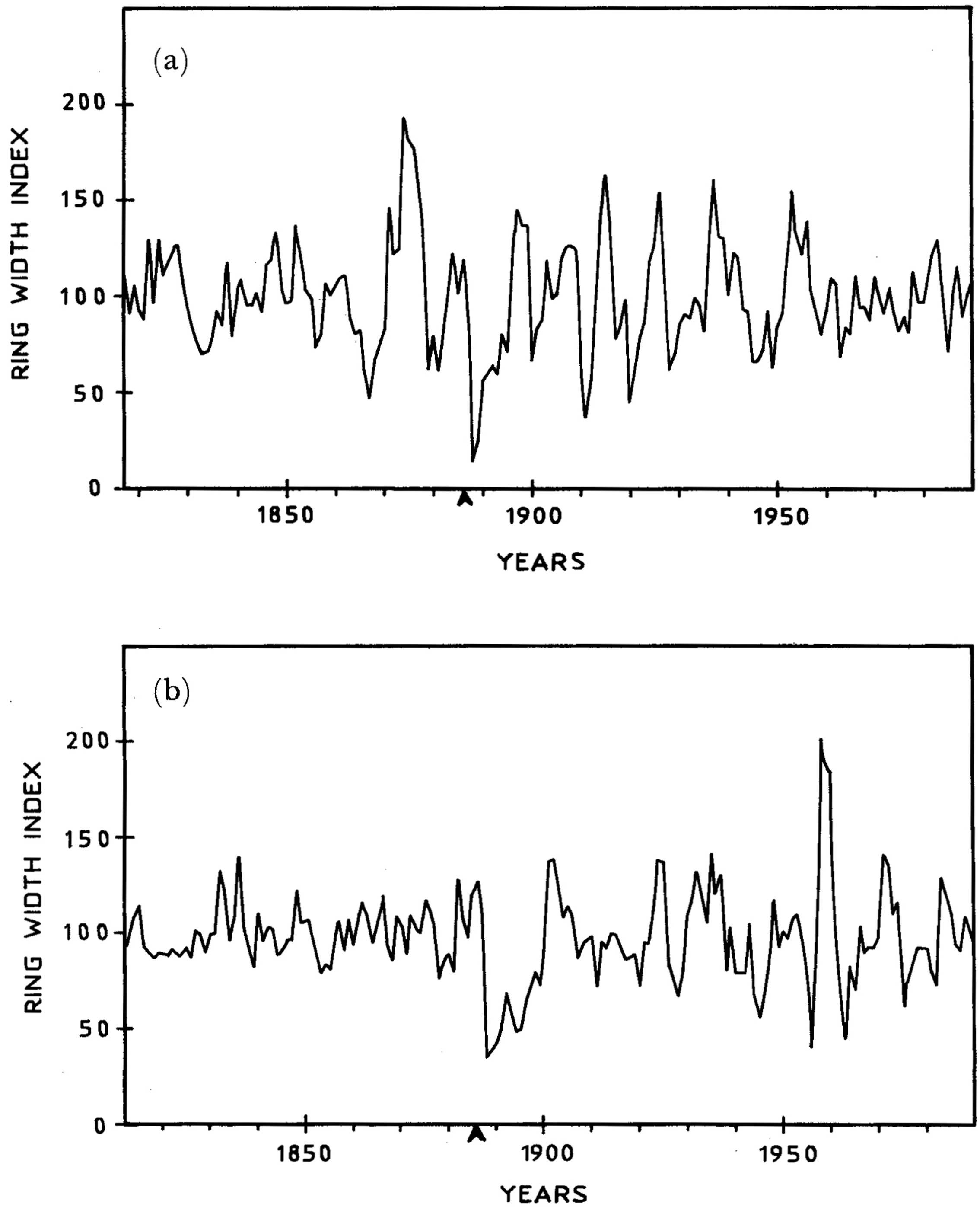

Fig. 3. Ring width chronologies of two trees showing long-term growth suppression

presence of such features of growth suppression over a wide area indicates a common origin; most probably in this case the earthquake of 1887.

The earthquake of 1911, the epicentre of which lay about 30 kilometres south of the town of Alma-Ata, did not produce an observable long-term pattern in the ring width of trees from any of the three study sites. Although the growth ring of 1911 was found to be narrow, there was an absence of long growth suppression. Moreover, the narrow growth ring cannot be proven to be the result of this event. Severe droughts occurred in the area in 1909 and 1910 which could also be the cause of the poor growth in a single season.

Conclusion

This study has shown that the 1887 earthquake caused intense damage to *Picea schrenkiana* growing on the northern slopes of the Zaileeskii Alatau mountains close to the epicentre of the earthquake. Intensive disturbance and tilting of the trees greatly altered the growth patterns of affected trees. By careful study, such growth suppression can be differentiated from the effects of climatic extremes and other, more localized forest stand disturbances, such as avalanches, hurricanes and landslides. To achieve this, cross-dating of trees over a wide area must be undertaken, including both the windward and leeward sides of mountains and avoiding locations such as avalanche routes and drainage channels. The greater the number of tree samples showing disturbance then the greater is the authenticity of the tree ring date; and the larger the area over which disturbance occurs, the greater the chance it results from an earthquake.

Thus, changed tree growth patterns, especially the suppression of growth in trees over a large area, may provide important aids to identifying earthquake events in the Holocene, to dating them accurately, and to locating the epicentre. The study of tree ring samples in areas presently subject to earthquakes would greatly help in furthering this type of research by allowing greater understanding of the links between earthquake intensity, geomorphic changes, physical damage to trees, and growth ring response over different distances from the epicentre.

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