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Origin, Age and Significance of Pseudotachylites from the Eastern Dabieshan Orogenic Belt, China

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Abstract Recent field survey in the eastern Dabieshan Mountains has revealed extensive occurrences of pseudotachylite. The pseudotachylite tends to occur as simple veins and injected networks along the NE-SW-trending fracture zones or shear zones, which are parallel to the Tanlu fault zone and cut all the pre-Cretaceous geological bodies. The characteristics of both the microstructures gained by the optical microscope and SEM imaging and the geochemistry between the pseudotachylites and their host rocks show that the pseudotachylites were formed mainly by ultracataclasis of their wall rocks in which they occur. The bulk K-Ar ages of the pseudotachylites yielded a narrow range of 81–93 Ma, and moreover the laser-probe $^{40}Ar/^{39}Ar$ dating of phengite overprinting on the pseudotachylite gave a weighted mean age of 78.9 Ma. These results show that the pseudotachylites from the eastern Dabieshan Mountains formed along the NE-SW-trending fault zone during the uplifting of the orogenic belt at 80–90 Ma, which places important constrains on the cooling and exhumation history of the Dabieshan Mountains during and after the late Cretaceous.

Key words: pseudotachylite, origin, microstructure, geochemistry, age, the eastern Dabieshan Mountains

1 Introduction

Pseudotachylites are dark aphanitic vein rocks being as both simple veins and networks along the paleoseismic fracture zone (Shand, 1916; Magloughlin et al., 1992). Fault-generated pseudotachylite is interpreted as a response to rapid faulting and as the fossil remnant of paleoseismic events (Sibson, 1975). It provides direct observation of the characteristics and behavior of the products along an exhumed fault. Yet, the origin and mechanism concerning the pseudotachylite formation has been in dispute. The generation of pseudotachylites as a response to rapid faulting has either been explained so far by cataclasis (Wenk, 1978) or melting due to frictional heating (Shand, 1916; Scott et al., 1953; Philpotts, 1964; Sibson, 1975; Allen, 1979; Yang et al., 1981; Spray, 1988, 1992, 1995; Magloughlin, 1989, 1992). Although most researchers now prefer a frictional melt origin, the number of crushing-originated pseudotachylites has recently been increasing in the world (Shimamoto et al., 1992; Lin, 1996, 1998) and the two tributes of pseudotachylite have the similar appearance and occurrence in the field. Meanwhile, the dating of pseudotachylite and thus the pseudotachylite-bearing fault zone has also been an aspect in this study field (Reimold et al., 1992; Kelley et al., 1994; Trieloff et al., 1994; Spray et al., 1995; Sherlock and Hetzel, 2001; Davidson et al., 2003).

Recent field survey in the eastern Dabieshan Mountains has revealed extensive occurrences of pseudotachylites. They tend to occur in NE-SW-trending fracture zones or shear zones. This paper will present some of the characteristics of the microstructures and geochemistry and the ages of the pseudotachylites and their host rocks; and will discuss the origin of the pseudotachylites and its significance for the exhumation history of the Dabieshan Mountains in the late Cretaceous.

2 Geological Setting and Field Observations

The Dabieshan orogen was formed chiefly during the Triassic collision between the north and south China blocks (Okay et al., 1992; Cong et al., 1994; Hacker et al., 2000; Suo Shutian et al., 2001; Zhong Zengqiu et al., 2003) The orogen underwent deep subduction and ultrahigh-pressure metamorphism (Cong et al., 1994). The coesite- and diamond-bearing eclogite indicate a subduction of the continental crust as deep as 120 km or more (Liou et al., 1996). The whole Dabie region can be divided into two massifs: the island arc complex belt in the northern Dabieshan Mountains and the HP to UHP metamorphic complex belt in the southern Dabieshan Mountains. Both are intruded by voluminous Cretaceous plutons and volcanic rocks. The age of the plutons ranges from 129.1±2.6 to 125.6±0.3 Ma (zircon) and the cooling ages yielded by the K/Ar and $^{40}Ar/^{39}Ar$ techniques for hornblende and biotite are 133 to 121 Ma (Hacker et al., 1996, 1998). The eastern part was cut sinistrally by the Tanlu fault, so that the orogen moved more than 530 km northwards to the Sulu region (Okay et al., 1992; Cong et al., 1994, 1995; Dong et al., 1998). The age of $^{40}Ar/^{39}Ar$ multi-diffusion-domain modeling in k-feldspar is 90-110 Ma (Ratschbacher et al, 2000) representing the reheating event along the Tanlu fault zone. A series of NE-SW-trending normal faults cutting all the above plutons and metamorphic sequences are developed in the east part of the Dabieshan orogen. The NE-trending faults are considered to be formed during the late Cretaceous and Cenozoic according to the relationship between the rock units and the fault zone.

The pseudotachylite occurred in the eastern Dabieshan Mountains tends to develop along the NE-SW-trending fracture zones or shear zones (Fig. 1). Being similar to most of the modes of occurrence in the literature, the pseudotachylites from the Dabieshan orogenic belt also occur as simple dikes (fault veins) and complex networks of veins, and they have sharp contacts and intrusive relations with the host rocks (Figs. 2 and 3). Single pseudotachylite veins range in thickness from less than 0.1 to 10 cm. Macroscopically, they exhibit aphanitic groundmass textures with varying concentrations of wall rock fragments. The two typical occurrences are found at the positions of Loc-1 in the northern Dabie orogenic belt (NDB) and Loc-3 in the southern Dabie orogenic belt (SDB). Mylonitic quartz bands are developed in the pseudotachylite matrix at Loc-1. The major wall rocks of the pseudotachylite are biotite-bearing quartz-feldspar gneiss in the cases of Loc-1, Loc-4 and Loc-5, while the wall rock of pseudotachylite at Loc-2. is epimetamorphozed muscovite-quartz schist. At Loc-3, however, there occurred either biotite-bearing quartz-feldspar gneiss or UHP biotite-plagioclase-gneisses.

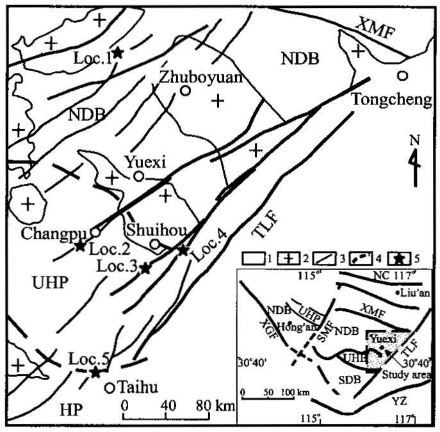

Fig. 1. Sketch map of the eastern Dabieshan Mountains, showing the localities where pseudotachylites have been found.
1. Dabie Group metamorphic complex (including paragneiss and orthogneiss); 2. Cretaceous granites; 3. fault zone; 4. inferred boundary fault zone; 5. localities of pseudotachylite; NC - North China block; NDB - Northern Dabieshan block; SDB - Southern Dabieshan block; HP-UHP - high- and ultrahigh-pressure metamorphic rocks; YZ - Yangtze block; MXF - Mozitan-Xiaotian fault; TLF - Tanlu fault zone; SMF - Shangcheng-Macheng fault; XGF - Xiangfan-Guangji fault.

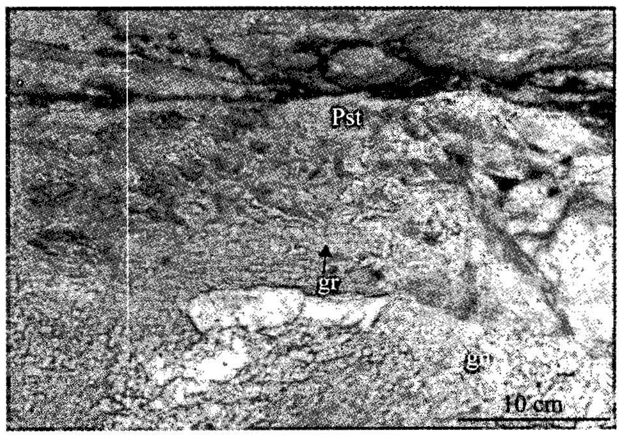

Fig. 2. Photograph of the field outcrop of pseudotachylites at Loc-1, Yuexi, Pingdeng.
gr - granite vein; gn - gneissic granite

3 Microstructure

Microstructural investigations were carried out for the aphanitic matrices of selected pseudotachylite veins using the optical microscope (OPT), scanning electron microscope (SEM) and X-ray diffraction. The SEM experiment was carried out on the JEOL/JSM-5610LV at the SEM laboratory of the Institute of Geology, Chinese Academy of Geological Sciences.

3.1 Features of OPT and SEM imaging

The features of the OPT and SEM imaging show that the matrix of the pseudotachylite from the Dabieshan Mountains exhibits dominantly cataclastic-ultracataclastic textures (Fig. 4a-c). Abundant crystal fragments and lithic clasts occur within the pseudotachylite matrix. The crystal fragments are almost quartz and feldspar. The matrix of the pseudotachylite from Loc-1 contains a lot of mylonitic

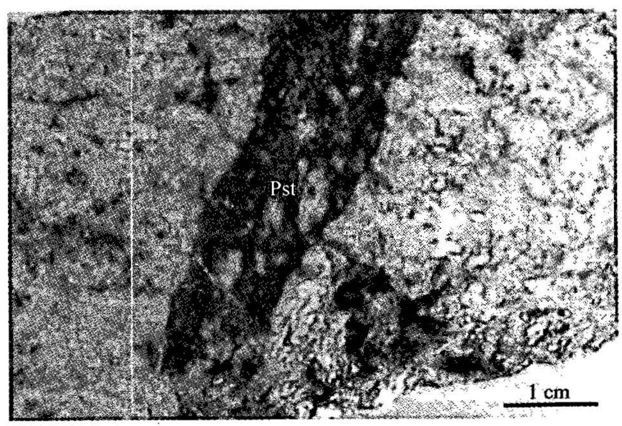

Fig. 3. Photograph of the hand specimen of pseudotachylites at Loc-3, showing the intrusive relationship between the pseudotachylites and its wall rocks.

lithic clasts (Fig. 4a), suggesting that the pseudotachylite is younger than the mylonite. The groundmass consists of micro-and ultramicro-crystalline material. Mica and amphibole rarely occur as crystal fragments. This feature is often interpreted to be the result of preferential melt of some mafic minerals such as biotite, chlorite and amphibole. No glass has been found in the matrix of these pseudotachylites, which implies that the pseudotachylites from the eastern Dabieshan Mountains were formed mainly by ultracataclasis. On the other hand, the SEM images of the pseudotachylite from Loc-1 show evident ultramicro mylonitic texture being composed of oriented minerals, such as feldspar, plagioclase and a large amount of pyrite with prevalent embayments along their margins (Fig. 4d), implying that partial melting might occur during the generation of the pseudotachylite (Magloughlin, 1992; Maddock, 1983). Moreover, microstructural characteristics of the images show evident progressive shearing fracturing from the wall rocks to the pseudotachylite and also show multiple generations of pseudotachylite (Fig. 4b). Sharp contacts can be found between the veins and neighbouring rocks or among different generations of pseudotachylites. The later generations of pseudotachylites always exhibit stronger cataclasis than the earlier ones, which shows that the preexisting soften fracture zone and the early-stage cataclasis play an important role in controlling the generation of pseudotachylites (Magloughlin, 1992). Moreover, the optical microstructure of the pseudotachylite from Loc-5 exhibits abundant network phengites overprinting on the pseudotachylite (Fig. 5). The number of Si atoms of the phengites (Table 1) defined by the microprobe is 3.38, slightly higher than that of the wall rocks (3.27). This indicates that the phengite was formed at higher pressures compared with its wall rocks.

3.2 Powder X-ray diffraction analysis

In order to identify the constituents and state of the mineral phase in the matrix of the pseudotachylites, two typical samples were selected from Loc-1 and Loc-3 and analyzed by means of the powder X-ray diffraction method. The measurement conditions are: graphite monochromator, scintillation counter, CuKα_1, X-ray generator 50kV, 80mA, continuous scanning speed 4.0°/min., divergence slit (DS)/ scattering slit (SS)=1.0°, receiving slit (RS)= 0.15 mm, 2θ position 3–70°.

The X-ray diffraction spectra of these pseudotachylites are shown in Fig. 6. All these X-ray diffraction spectra show a diffraction pattern of crystalline material, which is

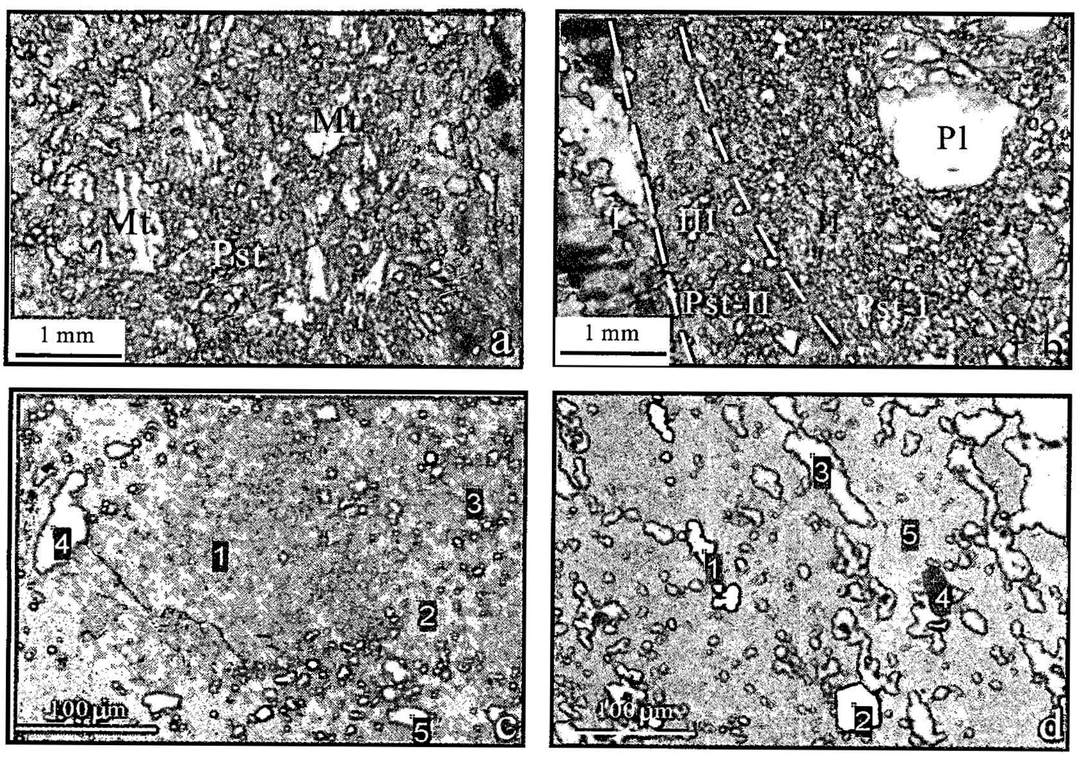

Fig. 4. Microphotograph of the microstructure of pseudotachylite obtained by OPT and SEM imaging.

Note: Numbers in the SEM images indicate the positions of mineral compositions analyzed with the energy spectrum method.

a. Mylonitic clasts (Mt) in the matrix of pseudotachylite (Pt) from Loc-1, indicating that the pseudotachylite is younger than the mylonite. b. cataclastic and ultracataclastic textures in the pseudotachylite and the multiple generations of pseudotachylite (Pst-I, II) and progressive shearing fracturing (stages I, II and III). Pl - plagioclase; c - SEM image of the matrix of the pseudotachylite from Loc-3: 1 and 3 - albite porphyroclasts, 2 - cryptocrystalline siliceous cement, 4 - K-feldspar; D - SEM image of the matrix of the pseudotachylite from Loc-1: 1 and 2 - pyrite, 3 - K-feldspar, 4 - plagioclase, 5 - cryptocrystalline siliceous cement.

very similar to that of the pseudotachylite from the Iida-Matsukawa fault, southern Nagano Prefecture, central Japan (Lin, 1996). The latter was thought to be formed at the shear zone by crushing or ultracataclasis of the host rocks (Lin, 1996). And the main crystalline peaks indicate the presence of quartz, K-feldspar and microclines in all the samples with minor amounts of muscovite, chlorite and ferro-bearing minerals in the samples from Loc-1. No glassy pseudotachylite has been found.

4 Chemical Composition

4.1 Major elements

The analytic results for 6 pseudotachylite samples from different localities and 4 samples of their host rocks are given in Table 2. The chemical changes between the pseudotachylites and their host rocks are illustrated in Fig. 7. Both the above data and diagram show that the pseudotachylites from different localities and their respective host rocks generally have similar compositions and fairly uniform variation curves of weight percent of oxides, which implies that the pseudotachylites from the eastern Dabieshan Mountains were formed mainly from the rocks in which they occur. On the other hand, during the development of the pseudotachylites in the Dabieshan Mountains, silica increases more or less in almost pseudotachylites. The increase is even up to 20%, such as for sample pt3-2, which is similar to that of the pseudotachylite from the Belleau-desaulniers area, Quebec, Canada (Philpotts, 1964), but inconsistent with that of most friction-melt-originated pseudotachylites in the literature, which is generally characterized by a decrease of SiO_2 (Lin A, 1998). Meanwhile, in all pseudotachylites except that from Loc-2, the content of Fe_2O_3 obviously increases compared to the wall rocks, which is similar to the cases described in the literature (e.g. Philpotts, 1964; Allen, 1979; Magloughlin, 1989; Spray, 1992). This probably results from the preferred cataclasis and decomposition of the abundant mafic minerals such as biotite and altered chlorite in the protolith.

4.2 Rare earth elements (REE)

The analytic results for the REE of the pseudotachylites and their host rocks from the Dabieshan Mountains are given in Table 3. The chondrite normalized REE patterns of the samples are illustrated in Fig. 8. The pseudotachylites and the source rocks have very similar patterns. Such a similarity suggests that the pseudotachylites were formed from the rocks in which they occur. This result supports the deductions made on the basis of petrography and petrochemistry.

5 Dating of the Pseudotachylites

Three pseudotachylite samples were collected from Loc-

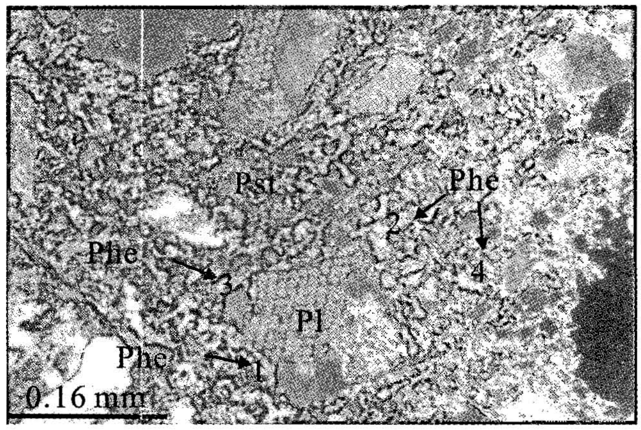

Fig. 5. Microphotograph of network phengites in the pseudotachylite matrix in the Taihu area, Anhui Prov.
Pl - Plagioclase; Pst - pseudotachylite; 1-4 - positions for the composition analysis of phengites.

Table 1 Contents (wt%) of phengites developed in the pseudotachylite and its host rock from Loc-5

Sample	1	2	3	4
SiO_2	48.84	46.58	49.24	47.24
TiO_2	0.45	0.87	0.47	1.11
Al_2O_3	26.40	24.75	27.09	27.60
Cr_2O_3	0.04	0	0.06	0
FeO	5.77	7.23	5.36	6.15
MnO	0	0	0	0.05
MgO	1.59	1.29	1.54	1.32
CaO	0	0.03	0	0
Na_2O	0.10	0	0	0.33
K_2O	10.07	9.35	10.00	10.27
Total	93.26	90.10	93.76	94.07
Si	3.383	3.367	3.379	3.269
Al^{IV}	2.154	2.107	2.189	2.249
Ti	0.023	0.047	0.024	0.058
Fe^{2+}	0.334	0.437	0.308	0.356
Mg	0.164	0.139	0.158	0.136
Na	0.013	0	0	0.044
K	0.89	0.862	0.875	0.907
Total of cation	6.961	6.959	6.933	7.019

Note: Samples 1–3 are newly-formed phengites in pseudotachylite at Loc-5 and sample 4 is phengite developed in wall rocks at Loc-5.

1, Loc-3 and Loc-5 and one wall-rock sampled from Loc-1 for whole-rock K-Ar dating. Furthermore, laser-probe $^{40}Ar/^{39}Ar$ ages of phengites newly formed in the pseudotachylite from Loc-5 were obtained. The samples were analyzed by the Chronological Laboratory of the Institute of Geology, Chinese Academy of Geological

Table 2 Bulk chemical compositions (wt%) of pseudotachylites and host rocks of the Dabieshan Mountains

Sample	Pt1-1	Pt1-2	Pt1-3	Pt1-4	Pt2-1	Pt2-2	Pt3-1	Pt3-2	Pt3-8-1	Pt3-8-2
SiO_2	67.27	68.24	69.50	71.88	75.51	77.66	70.60	91.03	59.06	63.02
Al_2O_3	16.53	15.60	15.07	14.02	12.84	10.35	14.39	3.38	16.39	11.50
TiO_2	0.44	0.28	0.24	0.25	0.37	0.75	0.30	0.05	1.24	1.46
MnO	0.07	0.02	0.02	0.06	0.07	0.03	0.11	0.10	0.24	0.18
MgO	0.77	0.57	0.64	0.40	0.36	0.35	0.32	0.14	2.81	3.41
FeO	1.08	1.44	1.20	0.95	0.68	0.32	1.24	0.56	3.86	4.24
Fe_2O_3	2.11	3.38	2.13	1.71	1.13	2.58	1.70	1.35	2.98	3.81
CaO	1.84	0.58	0.51	0.57	0.49	0.71	0.72	0.20	5.49	3.89
Na_2O	3.93	4.45	4.59	4.07	4.96	3.83	4.74	1.25	4.54	2.97
K_2O	5.40	5.59	5.50	5.38	2.61	2.08	5.20	0.92	1.15	1.25
P_2O_5	0.14	0.08	0.07	0.08	0.07	0.06	0.05	0.01	0.26	0.40
CO_2	0.12	0.09	0.18	0.05	0.14	0.05	0.05	0.09	0.09	1.05
H_2O	0.80	0.56	0.60	0.58	0.56	0.68	0.30	0.24	2.14	2.54
Total	100.5	100.88	100.25	100.0	99.79	99.45	99.72	99.32	100.25	99.72

Note: Analyzed with the XRF.
Pt1-1 – host rocks; 2, 3 and 4 – pseudotachylites from Loc-1; Pt2-1 and 2 – host rocks and pseudotachylite, respectively, from Loc-2; Pt3-1 and 2 – host rock (granitic gneiss) and pseudotachylite, respectively, from Loc-3; Pt3-8-1 and 2 – host rock (UHP gneiss) and pseudotachylite, respectively, from Loc-3.

Table 3 REE abundance (ppm) of pseudotachylites and their host rocks from the Dabieshan Mountains

Sample	Pt1-1	Pt1-2	Pt1-3	Pt1-4	Pt2-1	Pt2-2	Pt3-1	Pt3-2	Pt3-8-1	Pt3-8-2
La	117.30	70.52	55.83	70.82	38.76	80.99	120.5	19.34	27.22	15.96
Ce	230.70	127.6	102.4	128.1	86.7	149.6	235.9	30.61	50.64	31.80
Pr	18.32	10.36	9.08	11.06	8.44	14.98	21.12	3.36	5.10	3.34
Nd	62.62	33.61	28.26	35.74	30.7	57.15	77.51	11.31	20.41	14.11
Sm	8.26	4.06	3.74	4.29	5.49	8.79	9.96	1.78	3.96	2.99
Eu	1.59	0.9	0.87	0.91	1.55	2.29	0.7	0.18	1.28	0.95
Gd	7.67	3.56	3.53	4.13	6.07	7.38	9.3	1.68	5.62	4.52
Tb	0.90	0.38	0.45	0.5	1.00	0.83	1.31	0.23	1.09	1.14
Dy	5.08	2.55	2.40	2.94	6.39	5.2	5.91	1.13	8.03	6.41
Ho	0.95	0.54	0.45	0.51	1.38	1.11	1.17	0.21	1.62	1.44
Er	2.60	1.48	1.37	1.68	4.06	3.3	3.15	0.64	5.6	4.13
Tm	0.30	0.21	0.18	0.23	0.56	0.50	0.45	0.09	0.72	0.51
Yb	2.25	1.40	1.20	1.55	3.62	3.36	3	0.62	5.07	3.71
Lu	0.31	0.2	0.18	0.22	0.52	0.55	0.48	0.12	0.74	0.55
REE	457.85	257.37	209.94	262.68	195.24	336.03	518.1	77.04	137.10	91.56

Note: Analysed with ICP-MS by the State Geological Testing Center, CAGS.
Pt1-1– host rocks; 2, 3 and 4 – pseudotachylite from Loc-1; Pt2-1 and 2 – host rocks and pseudotachylite, respectively, from Loc-2; Pt3-1 and 2 – host rock (granitic gneiss) and pseudotachylite, respectively, from Loc-3; Pt3-8-1 and 2 – host rock (UHP gneiss) and pseudotachylite, respectively, from Loc-3.

Sciences. The procedures and conditions for the analyses were described in detail by Fu et al. (1987) and Chen et al (2002).

5.1 Whole-rock K-Ar ages

The whole-rock K-Ar ages of the above samples are given in Table 4. The ages range from 81.33±1.36 to 93.44±1.37 Ma. Mylonite, the host rock of the pseudotachylite from Loc-1, has an age of 93.44±1.37 Ma, yet the pseudotachylite itself has an age of 92.51±1.36 Ma, which is very close to that of the mylonite. This shows that the pseudotachylite was generated just following the mylonitization. The mylonitic texture displayed by the pseudotachylite ultramicromatrix indicates that the pseudotachylite was formed around a ductile-brittle transitional zone as deep as about 12 km. Besides, two pseudotachylite samples from Loc-3 and Loc-5 have ages of 81.33±1.36 Ma and 92.88±1.61 Ma respectively, which are close to that of the sample from Loc-1. This shows that the pseudotachylites from different localities in the eastern Dabieshan Mountains were formed contemporaneously.

5.2 Laser-probe $^{40}Ar/^{39}Ar$ ages

The laser-probe $^{40}Ar/^{39}Ar$ ages of the newly-formed phengites in the pseudotachylite from Loc-5 are given in Table 5. Four of the five ages obtained range from 79±11 to 87.9±3.2 Ma and only one age, 42.6 Ma, is relatively small. A weighted average age of 78.9±7.3 Ma, with the derivative of the square of error as the weight, was obtained by means of the ISOPLOT program. This value is basically the same as the whole-rock K-Ar age of the pseudotachylite from Loc-3 (81.33 Ma). The fact that two different dating techniques yield basically the same age shows that the determined ages are reliable. As for the age of 42.6 Ma, it is probably due to the uneven distribution of Ar isotopes in

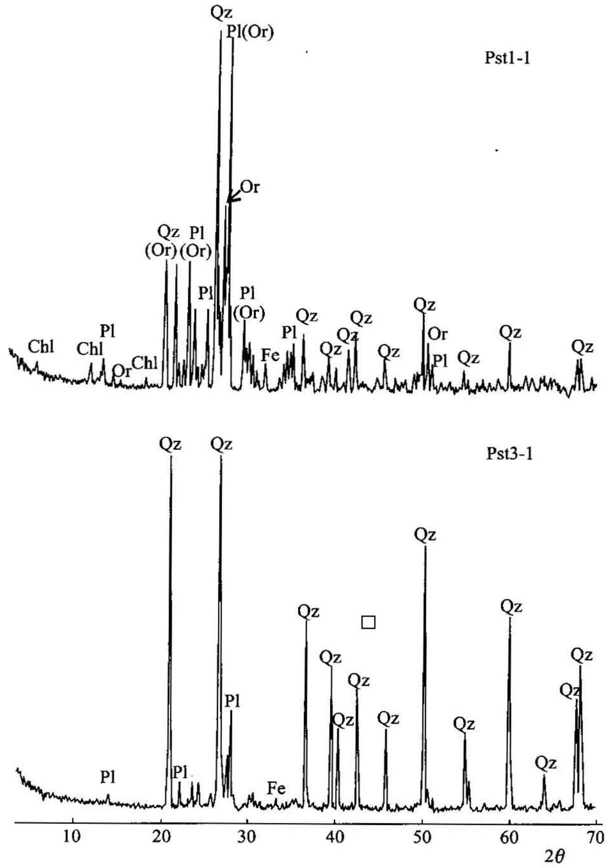

Fig. 6. Powder X-ray diffraction spectra of pseudotachylites from Loc-1 and Loc-3.
Qz - quartz; Pl - plagioclase; Or - K-feldspar or microcline; Chl - chlorite; Fe - iron-bearing minerals.

Table 4 Bulk K-Ar ages of pseudotachylites and the host rocks from the Dabieshan Mountains

Sample	Rock type	Weight (mg)	Grain size (mm)	K (%)	^{40}Ar (Radio) $\times10^{-9}$ (mol/g)	^{40}Ar (Radio) (%)	Apparent ages (Ma)
Loc.1-2	Mylonite	47.0	40-60	4.45	0.7402	96.25	93.44±1.37
Loc.1-3	Pseudo-tachylite	45.15	40-60	4.48	0.7375	94.87	92.51±1.36
Loc.3-1		45.0	40-60	3.09	0.4458	92.73	81.33±1.36
Loc.5-1		42.75	40-60	1.78	0.2942	89.52	92.88±1.61

Analyzed by Chen Wen in the Isotopic Laboratory of the Institute of Geology, Chinese Academy of Geological Sciences.

Table 5 Laser-probe $^{40}Ar/^{39}Ar$ ages of phengites overprinting on pseudotachylite from Loc-5 in the Dabieshan Mountains (J=0.015603)

Sample	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$^{39}Ar(10^{-14}$ mol.)	$^{40}Ar^*/^{39}Ar$	age (Ma)
p-1	11.1000	0.02778	0.08316	1.80	2.8930	79±11
p-2	5.4662	0.007669	0.08035	6.52	3.2012	87.9±3.2
p-3	2.4346	0.003061	0.08401	9.80	1.5313	42.6±1.3
p-4	3.8151	0.003774	0.08473	5.30	2.7014	74.5±1.7
p-5	4.3214	0.004762	0.007128	4.20	2.9100	80.1±1.4

Analyzed by Chen Wen in the Isotopic Laboratory of the Institute of Geology, Chinese Academy of Geological Sciences.

the phengite or the overprint of the late-stage geological events.

6 Significance

Cooling and exhumation of the Dabieshan Mountains during and after the late Cretaceous are very important tectonic events. The extensive occurrences of pseudotachylites developed along the NE-trending seismic fault zone in the eastern Dabieshan Mountains implies that there occurred extensive high-speed movements or paleoseismic events along the NE-trending strike-slip fault zone during the late Cretaceous and the early Tertiary period. The microstructural and geochemical

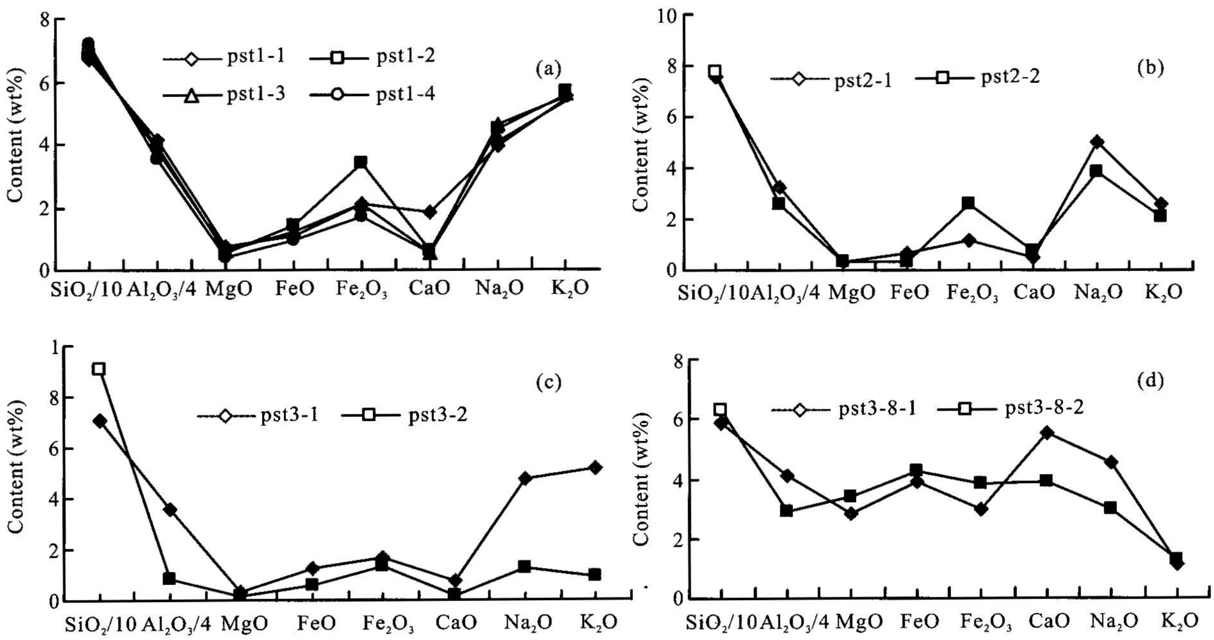

Fig. 7. Variation curves of lithochemistry of the pseudotachylites from different localities and their respective host rocks in the Dabieshan.

Note: a-d are from Loc-1, Loc-2, and Loc-3; samples the same as in Table 2.

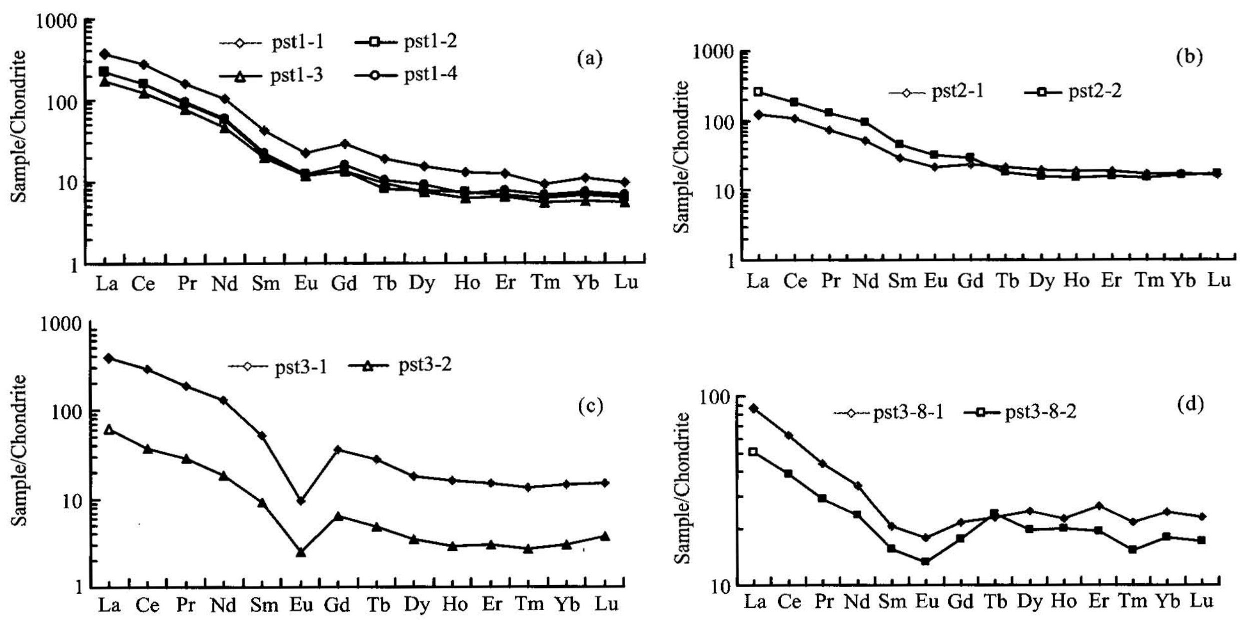

Fig. 8. Chondrite-normalized REE diagrams of pseudotachylites and their host rocks from the eastern Dabieshan Mountains.

Note: a-d are from Loc-1, Loc-2, and Loc-3; samples the same as in Table 3.

characteristics of these pseudotachylites show that they were formed mainly due to ultracataclasis of their wall rocks in which they occur.

Besides, the dating of pseudotachylites places important constrains on the cooling and exhumation history of the Dabieshan Mountains during and after the late Cretaceous. Based on macroscopic and ultramicroscopic mylonitic bands developed in the pseudotachylites, some geologists think that the pseudotachylites were formed during plate subduction or collision. Ages obtained by the bulk K-Ar dating of the crush-generated pseudotachylite and the laser-probe $^{40}Ar/^{39}Ar$ dating of phengite overprinting on the pseudotachylites demonstrate that the pseudotachylites were formed during 80–90 Ma. This result rules out the possibility that the pseudotachylites are related to the subduction which took place during 220–240 Ma and, instead, they were formed along the NE-SW trending faults during the uplifting of the Dabieshan orogenic belt during 80–90 Ma. Furthermore, the correspondence of the ages obtained from the above two different methods suggests that the bulk K-Ar dating technique were still an effective method to be used to determine the age of the crush-generated pseudotachylite and therefrom the age of the pseudotachylite-bearing fault, especially for the younger tectonic event.

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