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Slag particles from steam traffic Dating of non-laminated lake sediments

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Abstract

Slag and coal particles within lake sediments originate from the combustion of wood, oil and coal, from furnaces, wood fires and from steamships. They are transported through the atmosphere and deposited within sediments (RENBERG & WIK, 1984, 1985 a/b; WIK & RENBERG, 1987, 1991; WIK et al., 1986). The input of slag particles originating from steamships operating in the pre-alpine Mondsee and Attersee Lakes (Salzkammergut, Austria) was identified within the sediment fraction >63µm. The sedimentation rates during the last 113 resp. 112 years could be determined by a relatively simple counting method.

The increase and decrease of slag contents can be correlated with changes in intensity and frequency of steamship traffic and corresponding coal and oil combustion. Using the knowledge of the history of steamship navigation (WINKLER, without year) and the traffic intensity on the lake slag particles and its changing frequency within the sediment profile can be used as time markers and allow a „slag-stratigraphy" in non-laminated sediments.

Schlacken-Partikel aus der Dampfschiffahrt zur Datierung nicht laminierter See-Sedimente

Zusammenfassung

Schlacken- und Kohle-Partikel in Seesedimenten stammen aus der Verbrennung von Holz, Kohle und Öl, aus Hausbrand, Waldbränden und aus der Dampfschiffahrt. Diese Partikel werden über die Atmosphäre transportiert und in den Sedimenten abgelagert (RENBERG & WIK, 1984, 1985 a/b; WIK & RENBERG, 1987, 1991; WIK et al., 1986). Schlackenpartikel aus der Dampfschiffahrt auf dem Mondsee und dem Attersee (Salzkammergut, Oberösterreich) wurden in den Sedimenten in der Fraktion >63µm nachgewiesen. Die Sedimentationsraten während der letzten 113 bzw. 112 Jahre seit dem Beginn der Schiffahrt können damit über eine relativ einfache Zähl-Methode der Partikel bestimmt werden.

Die Zunahme bzw. die Abnahme der Schlackengehalte können korreliert werden mit der Intensität und der Frequenz des Schiffsverkehrs und der damit verbundenen Kohle- bzw. Öl-Verbrennung. Auf Grund der Kenntnis der Geschichte der Dampfschiffahrt (WINKLER, ohne Jahresangabe) *und der Frequenz des Schiffsverkehrs auf den Seen können die Schlackenpartikel und ihre wechselnde Häufigkeit in den Sedimentprofilen* als Zeitmarken verwendet werden. Damit ist auch in nicht laminierten Sedimenten eine recht genaue „Schlacken-Stratigraphie" möglich.

1. Introduction

Carbonaceous particles, soot particles or soot spheres larger than 5 µm (RENBERG & WIK, 1985 a/b; WIK et al., 1986) respectively fly-ash particles (WIK & RENBERG, 1991) were used as excellent indicators of pollutants from fossil fuel combustion over the last two centuries in varved and non-varved lake sediments. These particles can also be used as an indicator of deposition of other air pollutants like e.g. SO_4 or Pb. GRIFFIN & GOLDBERG (1981) analyzed particles from Lake Michigan sediments with respect to their morphology, structure and surface characteristics, indicating their origin from different

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fig. 1
Geographical location of lakes Attersee and Mondsee in Austria.

burning processes. In this research slag and soot particles deriving mainly from steamship traffic (sediment-fraction >63μm) on the two larger Austrian lakes were used for the determination of sedimentation rates over the last 120 years.

The Austrian Attersee and Mondsee Lakes are situated east of Salzburg in the foreland of the Northern Calcareous Alps (fig. 1). Both are typical hard water lakes with autochthonous biogenic epilimnetic and benthic carbonate production (MINDER, 1922; KELTS & HSÜ, 1978; SCHRÖDER, 1982). The lakes also show different allochthonous input of siliceous and calcareous clastic sediments (SCHNEIDER et al., 1990).

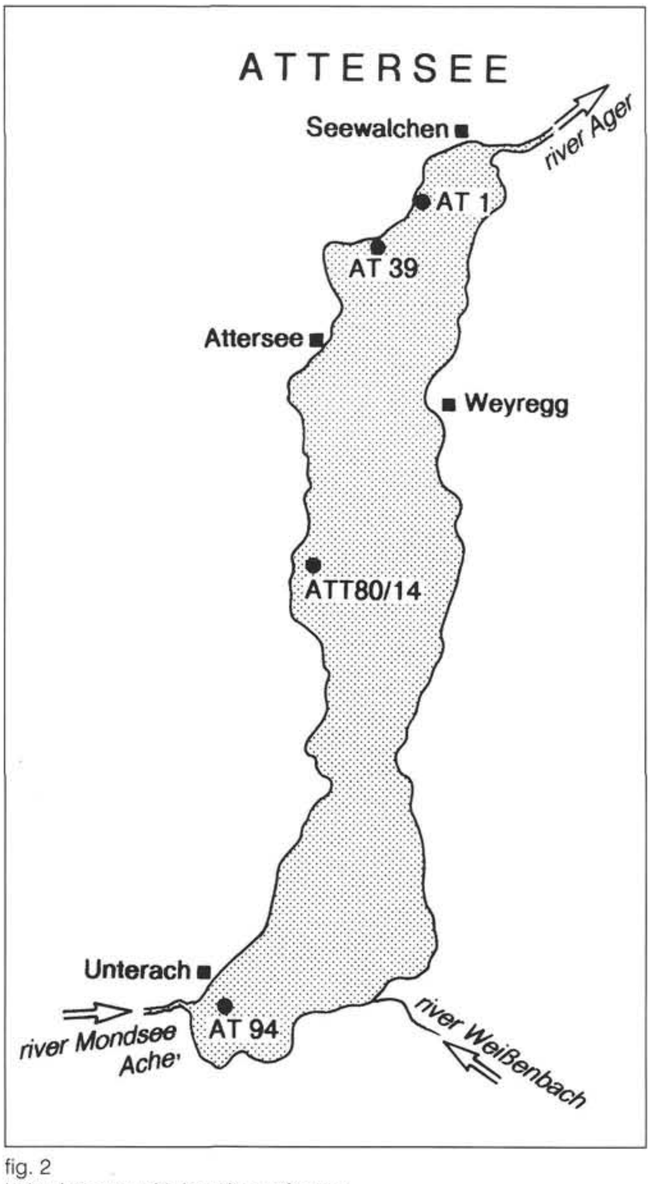

fig. 2
Lake Attersee with locations of cores.

Steamship traffic on Lake Attersee started in 1869 (SIAKALA, 1979; WINKLER, without year, p. 2-18). 1923 the maximum emission of smoke and soot from the chimney of the ship „Burgau" is reported by a documentation of H. WINKLER. The maximum of steam traffic occured at the end and soon after World War II. 1946 the steam traffic was the sole transport system for passengers (up to 425,000 persons per year) as well as for goods on the lake. From 1947 to 1949 the motor fuel for the steamships changed from coal to diesel. 1958 all electric boats was putted out of service and only Diesel motors was in function. On the motor ship „Unterach" a bigger Diesel motor was installed. After that time the passenger traffic decreased. The „Unterach" was scraped in 1979.

A detailed history of the steamship traffic on lake Mondsee was also documented by H. WINKLER (p. 19-24). Steam traffic on Lake Mondsee started in 1872 with one ship. 1887 a second ship was installed. The ships operated 3-6 times a day on the lake in 1889. During the summer of 1891 two further courses were additionally installed to the normal six courses. In 1907 steam traffic showed a new growth period. Because of the deficiency of coal and the bad economic situation during World War I only one ship operated. From the end of World War II to 1949 steamships were the most important transport medium in the region. The change to diesel motors was carried out in 1951, followed by a significant decrease in slag emission.

With the aid of selecting and counting slag particles from the sediment fraction >63μm and the knowledge of the steam traffic history, two sediment cores from Lake Mondsee and four cores from Lake Attersee were investigated (see fig. 2 and 3). The first results about slag particles in sediments from the northern and the southern basin of Lake Attersee were obtained by SCHRÖDER (1982) and BEHBEHANI (1984).

The most intensive sedimentation and the highest amounts of slag particles were found in sediments underneath the steam ship lines. In sediments older than the beginning of steamship traffic slag particles were almost missing within the fraction >63μm. Therefore, it can be concluded that for the Austrian lakes most of the slag particles derived from coal combustion on the steamships and not from other sources like in the case of the Swedish lakes (RENBERG & WIK, 1985 a/b; WIK & RENBERG, 1991) or from Lake Constance (WESSELS, 1995). Typical particles are documented on Plate 1.

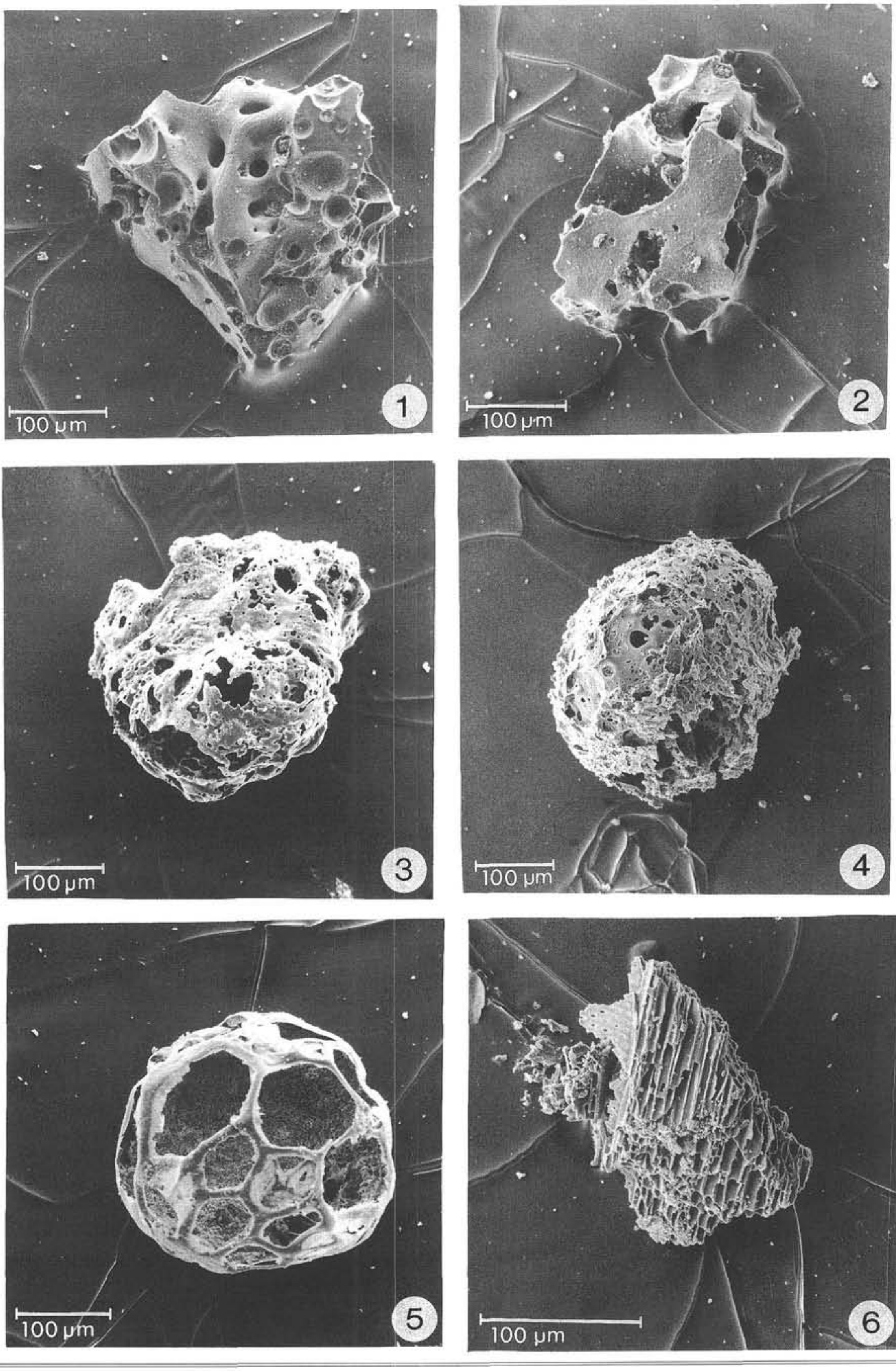

Plate 1
Characteristic particles from sediments of Lake Attersee and Lake Mondsee, selected from the fraction >63µm.
fig. 1+fig. 2: Slag particle with smooth surface texture from coal burning out of Lake Mondsee, station MON-3, 8 m water depth, 0-1 cm core depth; fig. 3+fig. 4: Spheroidal perforated slag-/soot-particle from coal burning out of Lake Attersee, station AT-39, 12 m water depth, 2-3 cm core depth; fig. 5: Very fragile spheroidal soot particle out of Lake Attersee, station AT-39, 12 m water depth, 2-3 cm core depth; fig. 6: Charcoal particle (fusite) from Lake Attersee, station AT-39, 12 m water depth, 2-3 cm core depth.

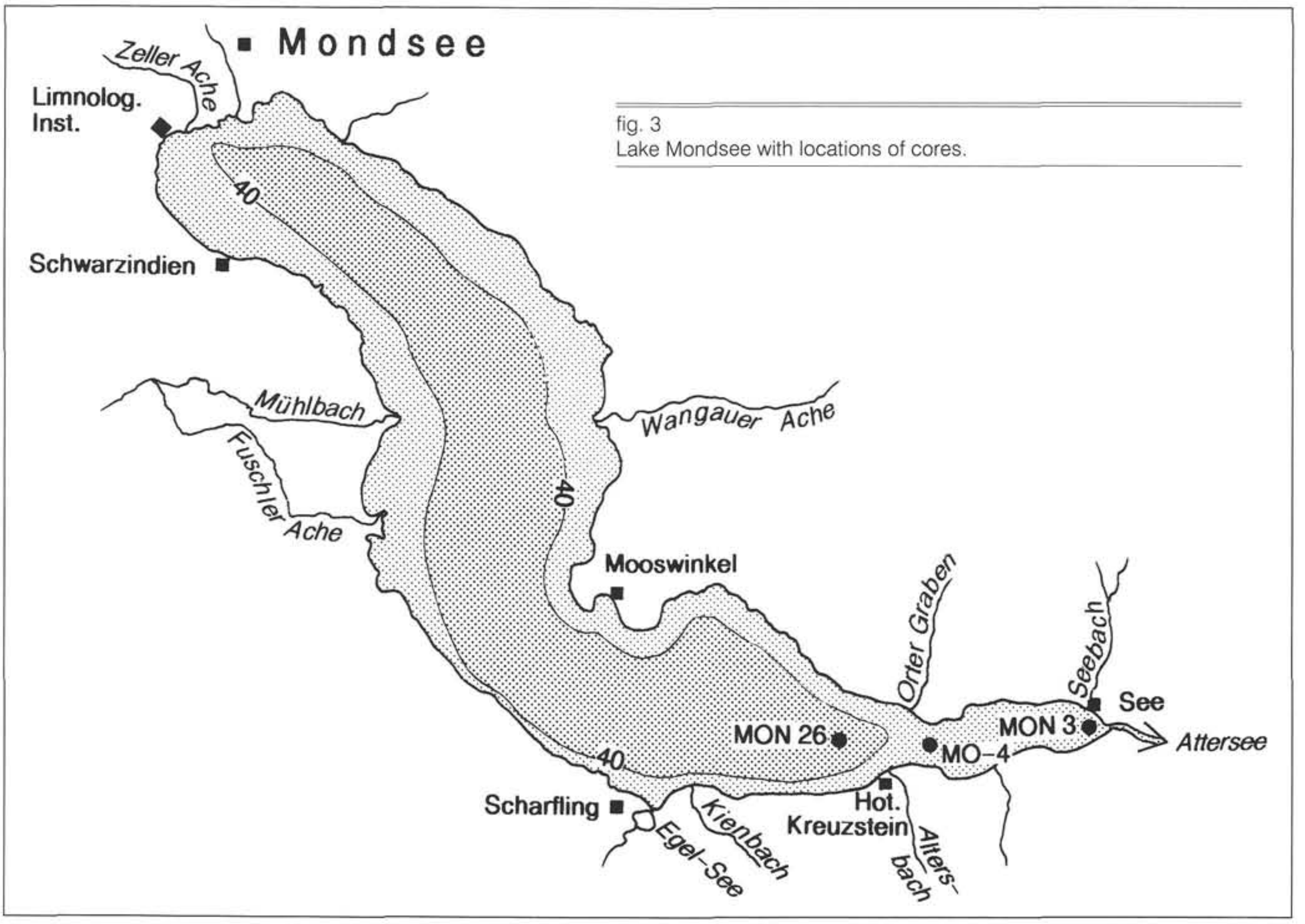

fig. 3
Lake Mondsee with locations of cores.

2. Methods

The sediment cores were taken by a gravity corer (MEISCHNER & RUMOHR, 1974) with a tube diameter of 5.8 cm from different localities on the lakes (fig. 2, 3).

Samples were taken from each cm within the first 30 cm of the cores. The sediment fraction >63µm was separated by wet sieving (Rhewum Schallfix vibro mesh) and dried at 60°C. The slag particles were picked out quantitatively by using a stereo microscope. They were counted and weighed exactly. The amount of slag particles (n/g in fig. 4/5) was calculated from the weight of the fraction >63 µm and the amount of counted particles.

3. Results

Fig. 4 shows the distribution of the slag particles in the sediment core MON-26 from 55 m depth in the eastern central basin of Lake Mondsee. The information about steam traffic frequency and intensity was given by H. WINKLER. They correspond most likely with the intensity of coal combustion and the following slag production. The same was done with the sediments from the northern shelf region of Lake Attersee (AT-39 from 12 m depth, fig. 5 and core AT-1 from 43 m depth, fig. 6). The historical data of steamship use in regards to Lake Attersee were taken from SIAKALA (1979) and H. WINKLER. The slight increase of slag particles in core MON-26 and in core AT-39 within 3 cm core depth cannot be interpreted exactly. A similar peak in core AT-1 (fig. 6) is missing. Further additional and detailed investigations are therefore necessary. Moreover investigations about the exact origin of the particles on the basis of their morphological and textural characteristics are necessary, like those which GRIFFIN & GOLDBERG (1981) carefully carried out in sediments from Lake Michigan.

From the variable chronological development of steamship traffic on both lakes and the subsequent variation of slag particle output, the sedimentation rates can be calculated. For the eastern central basin of Lake Mondsee (MON-26, 55 m water depth) a mean sedimentation rate over the last 113 years of 1.6 mm/a can be calculated. From 1944 on a re-

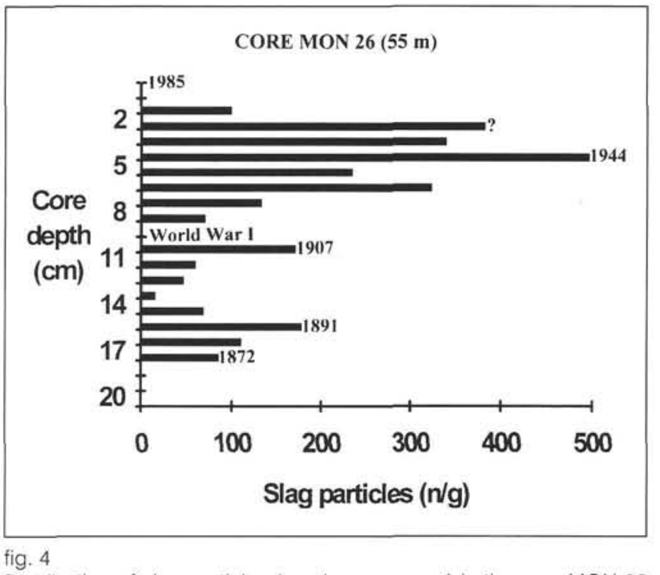

fig. 4
Distribution of slag particles (number per gram) in the core MON 26 from lake Mondsee (particles >63µm).

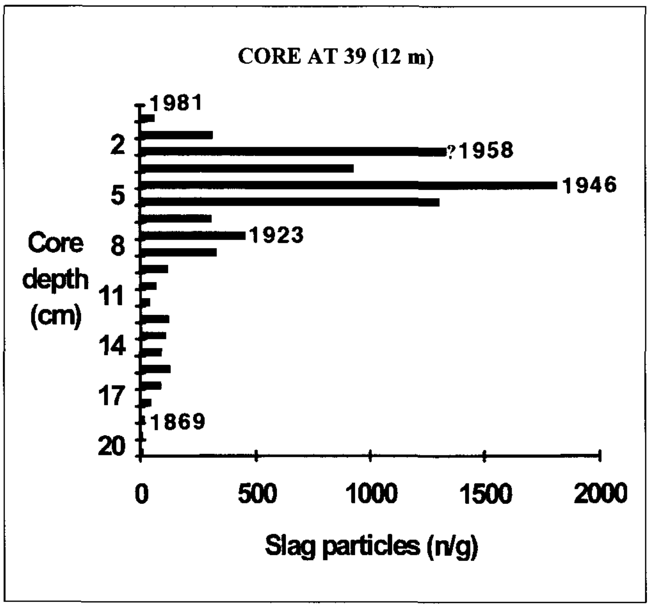

fig. 5
Distribution of slag particles (number per gram) in the core AT 39 from lake Attersee (particles >63μm).

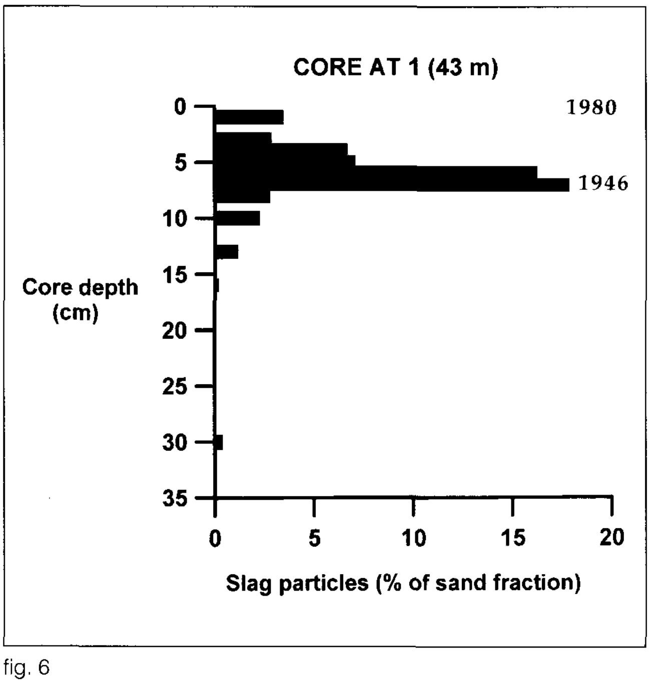

fig. 6
Distribution of slag particles (% of sand fraction) in the core AT 1 (data from SCHRÖDER, 1982).

duced sedimentation rate of 0.9 to 1,2 mm/a can be observed from fig. 4. For the station AT-1 of Lake Attersee a sedimentation rate of 1.8 to 2 mm/a is assumed since the last 35 years (fig. 6, data from SCHRÖDER, 1982). This is in good agreement with the ^{137}Cs- and ^{210}Pb-datings given by MÜLLER et al., (1983) from core AT-1. For the station AT-39 (12 m water depth, fig. 2) in Lake Attersee one can calculate a mean sedimentation rate (from 1869 to 1981) of 1.7 mm/a. For the last 58 years the sedimentation rate on station AT-39 decreased to 1.4 mm/a according to the slag stratigraphy. GHORBANI (1990) calculated a mean sedimentation rate within the last 112 years of 1.6 mm/a for the station AT-94 (see fig. 2). This agrees with the results of BEHBEHANI (1984). Table 1 shows the general sedimentation rates at respective stations within the lakes.

Table 1: Sedimentation rates at different locations on the Mondsee and Attersee Lakes (for stations see fig. 2 and 3)

station	depth (m)	mean sedim. rate (mm/a)
MON 3	8	1.7
MON 26	55	1.6
AT 94	82	1.6
AT 39	12	1.7
ATT 80/14	32	1.5
AT 1	43	1.8-2

It must be pointed out that the sedimentation rates are only valuable for a specific station. East of station MON-26 at another station (MO-4, 30m depth) in Lake Mondsee IRLWECK (1985) and IRLWECK & DANIELOPOL (1985) found a higher sedimentation rate (2.5 mm/a) determined by ^{137}Cs- and ^{210}Pb datings. These variations are caused by bottom morphology, different and changing influences by river input and differenciated sediment distribution mechanisms within a lake. In the case of MO-4 (east of MON-26), the input of two rivers (see fig. 3) and the eastward directed currents result in slightly higher sedimentation rates.

4. Conclusions

Slag particle analyses from sediments in lakes with well documented steamboat traffic history offer a relatively simple method for determining sedimentation rates. Besides a microscope which is used to examine the fraction >63μm there is no need of highly sophisticated laboratory equipment. These investigations show that with the help of this "slag-stratigraphy" a chronological classification of sedimentation is possible for the time since the beginning of the industrial revolution (see also RENBERG & WIK, 1984; WIK & RENBERG, 1991). This is especially useful for oligotrophic and mesotrophic lakes with non-laminated sediments like the Attersee and Mondsee Lakes. One precondition is a documentation as detailed as possible of the history of steamship navigation.

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