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Non-cored hot point drills on Hans Glacier (Spitsbergen), method and first results *)

ABSTRACT: Hot point drills were carried through in the Hans Glacier (Spitsbergen). For that purpose a non-cored hot point drill of 700 wattage was constructed. It was used among others for installing the ablation-movement stakes, for hydrological observations and in the boreholes an ice temperature was controlled.

Key words: Artic, Spitsbergen, methods of glaciology, hot point drill

1. Introduction

During glaciological works there is frequently a need for drillings in a glacier. Typical borehole sets for their weight and freezing of borings--water can be hardly used as the technology is complicated and the costs are immense. Such methods are frequently used in Antarctic (Sekurov 1967, Paige 1969, Ueda and Garfield 1969). Instead of mechanical drills so-called hot point drills keep more and more common. A borehole or a core is melted out by a heating element of special construction. Two types of such elements are used, differing in their feeding system. In one of them the heating element is provided in heat by a reservoir warmed up by petrol or by propane-butane gas (among others Lliboutry 1956, Kasser 1960, Howorka 1965). Such drills are after all seldom used and only for installing the ablation-movement stakes, due to their small efficiency and a limited range. Most frequently hot point drills include electric heaters fed from a current-generating aggregate. Most constructions of that kind are similar and there are differences only in the technical parameters of the heating element. For Soviet Antarctic expeditions many drill sets for a hot point method have been constructed (Barkov, Bobin and Stepanov 1973, Kudrjasov and Fisenko 1973, Kudrjasov et al.

*) This work was made during the expedition of Institute of Geophysics Polish Academy of Sciences on Spitsbergen in the summer season of 1979.

1973, Bobin and Fisenko 1974). But these sets are very heavy and need a mechanical transport so, they are not to be used on mountain glaciers. Quite a light heater (20 kg) has been constructed in the United States for core sampling (Shreve and Kamb 1964). It is worthy of notice for its weight and a very simple construction. A heater that melts out deep boreholes in ice without core sampling is the simplest type of a hot point drill. Such drills were described among others by Stacey (1960), Ekman (1961), Aamot (1968). They have been used mainly for installing the ablation stakes on mountain glaciers. Technology of non-cored hot point drilling is widely applied by Soviet glaciologists of Institute of Arctic and Antarctic at Leningrad and of Moscov University. Morev (1976) is the one who constructed most of drills of that kind. His non-cored hot point drills melt in with a speed of 6 — 20 m/h (wattage 1—4 kW). Since many years they have been used by glaciologists of Institute of Geography, Soviet Academy of Sciences (Grosvald et al. 1973, Troickij et al. 1975, Zagorodnov et al. 1976) for measurements of glacier thickness, their temperature and for installing of the ablation-movement stakes. An interesting drill was constructed by Golubev, Suchanov and Chromov (1976) from Institute of Geography, Moscov University. A maximum speed of heater melting-in (15 m/h) was received at 300 wattage only due to a small diameter of the heater.

2. Description of a drill

For the construction of a hot point drill an experience of other workers, mentioned in the introduction, was taken into account. It has been in so far difficult because there were only general description of a drill usually in the papers, without any scheme or section in most cases.

The heater is the most important part of the constructed drill (Fig. 1) as the process of a borehole melting out depends on its thermal capacity. A section of the heater is presented on Fig. 2. A particular attention was paid to a shape of the melting surface of a copper fluke (Shreve 1962). The copper fluke *(a)* is wound by a coil *(c)* of 700 wattage, insulated with mica *(e)* and ceramics (*d*, ceramabond 503). The whole part is covered by a bushing of an acid-resisting steel *(f)* connected with a copper fluke by a threaded part. For heat insulation of the heater — coil from the feeding wire (*j*), a ceramic fuse (*g*) and an asbestic tile (*h*) are used. A silicon gum (*i*) is used as a water gasket.

After several working hours of the heater the acid-resisting steel of the bushing *(f)* was found to be unsuitable; leaks at the threaded part were created in result of various coefficients of thermal expansion of copper and acid-resisting steel. Thus, the copper fluke kept screwing out. Then, it was avoided by a brass bolt (*b*). The heater is connected with a so-called guide (Fig. 1b) by a threaded part made of a brass pipe. The guide includes a moving oval part of the same diameter as heater. The guide is a control of vertical melting out of the borehole. Such method was applied by Morev (1976). It is very simple but needs a great accuracy

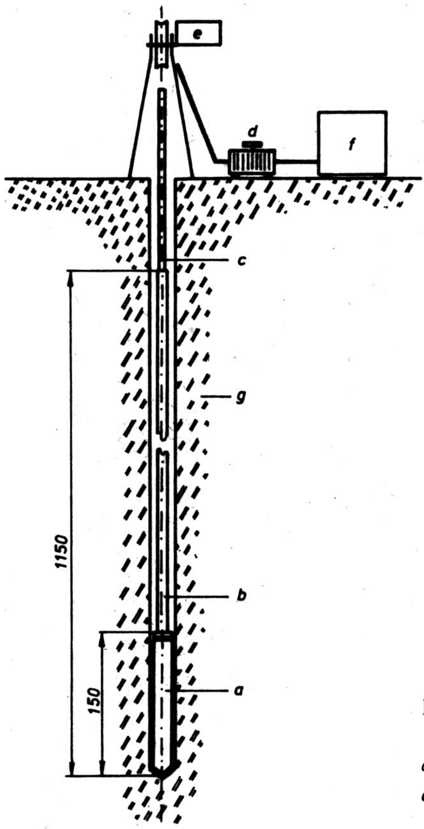

Fig. 1. Sketch of a site for a hot point drill in ice
a — heater, *b* — guidebar, *c* — electric cable, *d* — self transformer, *e* — recorder-stand, *f* — current-generating aggregate, *g* — glacier.

at starting moment of the drilling and keeps the vertical direction. The good solution was applied by Aamot (1968) — so-called buoyancy stabilized drill in which the guide role was played by an air reservoir over the heater. The heater was fed by a current-generating battery (220 V, 1.5 kW) with the use of two-strand electric (in a gum coat), calibrated at every 0.5 m. The cable was also a carrying wire. During the work the self-transformer was used for regulation of the current voltage. Until the heater was entirely melted in, it was fed with a current of 100 V voltage; after a water appeared in a borehole the voltage was increased up to 220 V. There were also the cases when in the hole of several metres depth, the water was drained after reaching a crevasse. Then, the voltage was decreased for several minutes to 100 V to avoid on overheating of the coil. During the work a drilling speed was controlled all the time. For this purpose a calibrated cable at every 0.5 m was used and an adapted recorder "Wałdaj" or a suitable stand. Beneath, the principal dimensions and parameters of the constructed hot point drill are noted:

a) outer diameter of a heater — 27 mm,
b) lenght of a heater (with thermal-electrical insulation) — 150 mm,
c) lenght of a guiding part — 10000 mm,

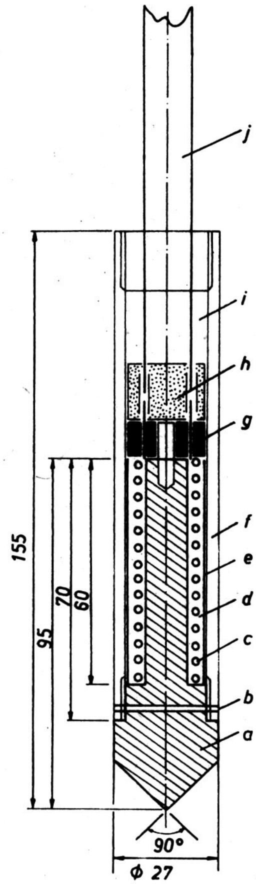

Fig. 2. Section of heater
a — copper fluke, *b* — bolt, *c* — coil, *d* — ceramics, *e* — mica, *f* — coat of acid-resistant steel, *g* — ceramic insert, *h* — asbestic tar, *i* — silicon gum, *j* — feeding cable

d) outer diameter of a guiding part — 16 mm,
e) diameter of a melted hole — 40 mm,
f) heater wattage — 700 W,
g) feeding: monophase current — 220 V,
h) speed of melting in (maximum one noted) — 8.5 m/h,
i) weight without a feeding cable — 1.4 kg.

3. Description of the work course

Some problems connected with the work of the non-cored drill have been already mentioned. As accentuated by Morev (1976) a method of a hot point drilling is simple and comfortable but it needs certain experience and attention. After preparing 0.5 m long borehole section the farther melting occurs under the weight of the heater. A diameter of the melted out borehole is 40 mm. After putting an electric cable through the stand or recorder circle the melting speed was controlled or registered. With a depth increase a freezing over of the borehole occured resulting in a decrease of its diameter. For a reduction of this process a methylated spirit was pourred into the borehole in amount depending on a borehole depth; generally, no more than a litre per 3—4 m of the borehole. But for all the time a freezing over of the borehole should be controlled by checking its patency. The methodology was proposed that enabled to avoid the use of methylated spirit what could result in a decrease of the weight of all transported instruments over a glacier. During drilling, another heater (300 W) of a suitable shape could "clean" the freezing-over hole. While drilling many times the temperature of hydrous spirit solution was controlled. The temperature 0.5 m over the heater equalled 8—10°C and quickly decreased upwards: 1.0 m — 1.0—1.5°C, 2.0 m — 0.2°C. It was also found that air coming out of the melting ice, considerably decreased the freezing-over of the borehole. The melting-in speed was very varying and usually changed rapidly. A drilling should be done without breaks in the aggregate work because every break caused an increase of freezing over; so it could result in freezing fast of the heater or of the cable. Such event occured in August 1979 at the Hans Glacier. A break in the aggregate work at a depth of 28.5 m caused a freezing fast of the cable to the borehole wall and resulted in a loss of the drill. In case of feeding breaks there is then a necessity of taking the heater out to the glacier surface.

4. Results

After test drillings the measuring works at the Hans Glacier were started; the latter was an object of complex studies during the expedition of Institute of Geophysics PAS, Warsaw. The boreholes done with a hot point drill were used for installing the ablation-movement stakes. For this purpose the aluminium pipes were prepared of 22 mm diameter and 1.5 or 2.0 m long. Depending on the depth at which they were installed they were connected one with another to form sets. Every connection was marked by an aluminium plate with a printed stake number and the distance to that place. In a transversal section at the Hans Glacier (about 100 m above sea level) seven stakes were installed at a depth 5 to 10 m. As the boreholes were done at the end of July the analysis included only a part of the ablation season. In August, at the Hans Glacier 70—75 cm ice layer melted and until 15th September 80—85 cm layer. The data in these places are collected all the year round. At the end of the ablation season geodesic positions of the stakes were defined. After repeating of this work a movement of the glacier in the analyzed section can be defined.

During drilling the level of water-solution in the borehole keeps gradually lowering as the water occuppies a smaller volume than the melted ice. At the borehole diameter of 40 mm and the depth of 7 m the water level was stabilized at 40—55 cm. With an increase of the borehole depth a lowering of the solution level in a borehole was slower and slower: at 10 m — 60—65 cm, at 15 m — 70 cm, at 20 m — 75 cm. Such measurements were not always possible. Several times, there occurred in the analyzed section a water run-off in a borehole after reaching a draining crevasse.

In a single case the water got out of the borehole reaching 0.5 m altitude. As it was stated by Golubev (1976) an investigation of the water level in the borehole could result in many information of structure and hydrology of a glacier, particularly with a use of a recorder (Golubev, Suchanov and Chromov 1976).

Use of a hydrous solution of a spirit to protect a borehole from freezing over enabled to carry through the observations of glacier ice temperature. Morev (1976) found that due to no convection of hydrous solution of spirit in a borehole its temperature was stable and equalled the ice temperature. So, it enabled to collect quite precise data. To check this method special controling measurements have been carried through. In a borehole 14.5 m deep (filled with a hydrous spirit solution) the measurements with a termistor thermometer were done at every metre depth. After collecting the data, indicators of resistance thermometers (Cu) were put at a depth of 8 and 14.5 m. After three days when the borehole was completely frozen the control investigation has been done. The temperature was found then to be at these depths the same as the one registered by a termistor thermometer and equal 0°C. All the data were collected at the glacier altitude of about 100 m above sea level. Some results are presented on Fig. 3.

Sverdrub (after Troickij et al. 1975) was among the first who collected the data of Spitsbergen glacier temperatures in Isaken Plateau at 850 m above sea level. Troickij et al. (1975) have done many temperature investigations but mainly in the upglacier zones (accumulation zone). On the ground of this paper data (collected in August and September) three thermic beds within the glacier could be distinguished: the bed 0—1.5 m of varying temperatures from 0° to −3.8°C, the bed 1.5—7.5 m of temperatures below 0°C and the bed 7.5—24 m of 0°C ("warm ice"). A short research period, small number of data and their slight spatial differentiation (transversal section at 100 m above sea level) did not allow to draw far-reaching conclusions. Baranowski (1977) included the glaciers of the Hornsund area into his sub-type of subpolar marine glaciers of high geographical latitudes. He found that the ablation zones were generally cool (i.e. the beds beneath the annual temperature fluctuations) and in the glaciers of a sub-polar, slightly continental sub-type a "warm-ice" could occur in the ablation zone. Results of investigation and hydrologic observation at the Hans Glacier allowed to find that this part of the glacier was "warm" temperate glacier. It was also supported by a fact that most meltwaters flowed away englacially. Baranowski (1977) found that "naledi" could be in some cases an index of thermic regime of a glacier. The Hans Glacier front occurred mainly in the Hornsund Fiord. In winter, at the frozen fiord no water outflow was observed at the glacier front (Szupryczyński, personal communication). It may be an evidence for lack of this phenomenon, but on the other hand it must still be taken into account. For a final explanation of the problem a control of water temperatures and water salinity should be studied in winter nearby the glacier front.

Generally, a speed of a borehole melting was discussed at hot point drills as the working capacity of the instrument. Golubev, Suchanov

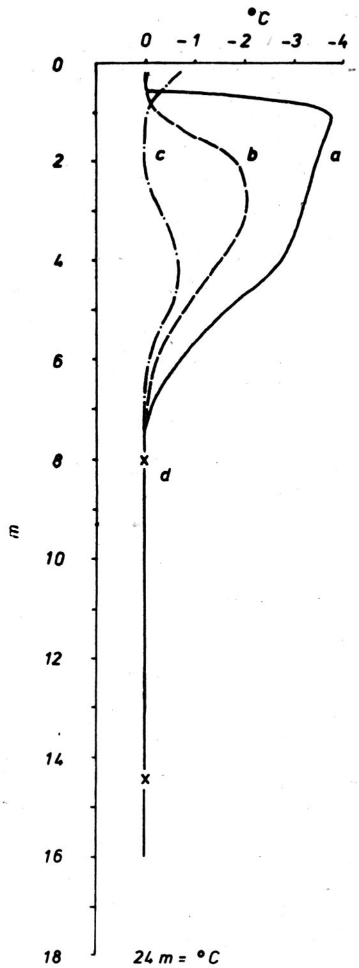

Fig. 3. Some profiles of temperature of the Hans Glacier prepared in 1979
a — on 2nd August, *b* — on 22nd August, *c* — on 25th August, *d* — on 11th September.

and Chromov (1976) suggested that this value could be a method of describing the inner structure of a glacier. The specific requirements for a drilling were mentioned in the introduction. The curve (Fig. 4) presents the examples of a melting speed of the heater at four sites. Slowing down and accelerations (controlled in 0.5 m intervals) occurring in turn were typical during drilling. Such changes reflected a bedded glacier structure (density changes of the ice), so distinct in crevasses. But they also depended on other factors as ice temperature and content of mineral matter. A precise analysis of relation between a drilling speed and physical properties of ice was carried through by Golubev, Suchanov and Chromov (1976) at the Dzankuat Glacier in the Caucasus. Such method still needs to be supplemented particularly in calibration of a heater for various ice kinds. In the diagram (Fig. 4) *g* and *e* curves reflect a course of drilling at the Hans Glacier by a stream line close to *G* and *E* ablation-movement stakes. It was a strongly recrystallized ice of great density. The melting speed was there from 1.3 to 3.0 m/h. 300 m away the melting speed was

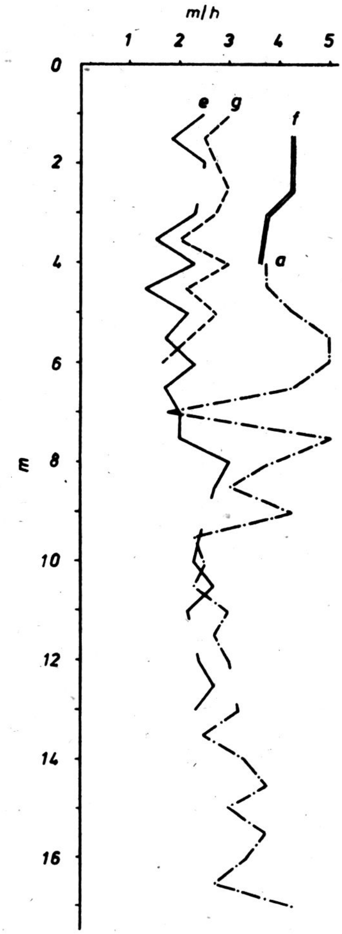

Fig. 4. Some examples of a speed of drilling by hot point drill at the Hans Glacier in August and September 1979, at an altitude of about 100 m above sea level
a, e, f, g — speed profiles of a borehole close to *S, E, F, G* ablation-movement stakes.

considerably greater and equal 1.7—5.0 m/h (close to *E* and *F* rods). For every analyzed curve a distinct change of melting speed occurred at a depth of 7—8 m. It was noted then in the transition zone mentioned already with a temperature below 0°C up to 0°C. Beneath a depth of 9 m similar speeds were observed in all boreholes.

5. Conclusions

A method of hot point non-cored drill was found to be very simple and comfortable with a use of light, portable currentgenerating aggregate but it needed to comply certain principles. It allowed for a quick and solid installation of points at the glacier — mainly of ablation-movement stakes. The section installed at the Hans Glacier (at about 100 m above sea level) with an annual ablation of about 1.5—2.0 m, can be used for 5—6 years for collecting the data until the entire melting out of the stakes. The described method enables a precise control of glacier temperature if using good thermometers. The investigation carried suggests that the ablation part of the Hans Glacier is "warm". An important information of a glacier structure may come out of observations of the water level in a borehole and registration of melting speed of borehole (at stabilized voltage).

The tested drill is a prototype. The next specimens will include some changes as smaller diameter of the heater, greater wattage. Instead of spirit an extra probe of 300 wattage is to be used (without a guide part) for "cleaning" a freezing-over borehole.

6. Summary

In summer 1979 hot point drills were done with a use of a hot point drill 700 W (of an original construction) at the Hans Glacier, (Spitsbergen), (Figs. 1 and 2). The technics was used for measurements of ice temperature, for installing the ablation-movement rods and for hydrologic observations and glacier movement. In the boreholes a water level was controlled what supplied with much information of glacier hydrology. After filling the boreholes with a water solution of a spirit the measurements of ice temperatures in vertical sections were done. Also, an attempt of registration of melting-in of a heating element of a drill was carried through; the speed depended on ice density and equalled from 0.5 to 5.0 m/h (Fig. 4).

7. Резюме

Летом 1979 года проведено бурения с помощью термоэлектрического долота с силой 700 W (оргинальная конструкция) на Леднике Ханса (Шпицберген) — (рис. 1 и 2). Этот метод использовано для измерения температуры льда, установки абляционно — двигательных рейков и гидрологических наблюдений, а также движений ледника.

В отверствиях измерено уровень воды, что дало много информации о гидрологии ледника. После залива отверствий водяным раствором спирта проведено измерения температуры льда в вертикальных профилях. Проведено тоже попытку регистрации скорости погружения нагревательного элемента долота, которая зависит в главной мере от плотности льда и достигает с 0,5 до 5,0 м/ч (рис. 4).

8. Streszczenie

Latem 1979 roku przeprowadzono wiercenia przy pomocy świdra termoelektrycznego o mocy 700 W (o oryginalnej konstrukcji) na lodowcu Hansa, (Spitsbergen), (rys. 1 i 2). Metodę tę wykorzystano do pomiaru temperatury lodu, instalacji tyczek ablacyjno-ruchowych i obserwacji hydrologicznych oraz obserwacji ruchu lodowca.

W otworach mierzono poziom wody, co dało dużo informacji o hydrologii lodowca. Po zalaniu otworów wodnym roztworem spirytusu przeprowadzono pomiary temperatury lodu w profilach pionowych. Przeprowadzono także próbę rejestracji prędkości wtapiania elementu grzejnego świdra, która to prędkość zależy głównie od gęstości lodu i wynosi od 0.5 do 5.0 m/h, (rys. 4).

9. References

1. Aamot H. W. C. 1968 — A buoyancy-stabilized hotpoint drill for glacier studies — J. Glaciol., 7: 493—497.
2. Baranowski S. 1977 — Subpolarne lodowce Spitsbergenu na tle klimatu regionu — Wyd. Uniw. Wrocł. Studia Geograf., 31: 19—33.
3. Barkov N. I., Bobin N. E., Stepanov G. K. 1973 — Burenija skvaziny v lednikovom pokrove Antarktidy na stancii Vostok v 1970 gode — Sov. Antarkt. Eksp. Inform. Bju. 85: 22—28.
4. Bobin N. E., Fisenko V. F. 1974 — Opyt termoburenija skvazin s otborom kerna v prochodnych uslovijach — Sov. Antarkt. Eksp. Inform. Bjul. 88: 74—76.
5. Ekman S. R. 1961 — Thermal drilling in Insfallglaciären, Kebnekajse — Geogr. Ann., 42, 420 pp.
6. Grosvald M. G., Krenke A. N., Vinogradov O. N., Markin V. A., Psarevat V., Razumejko N. G., Suchodrovskij V. L. 1973 — Oledenenie Zemli Franca-Iosifa — Moskva, 117—232.
7. Golubev G. N. 1976 — Gidrologija lednikov — Leningrad, 247 pp.
8. Golubev G. N., Suchanov L. A., Chromov R. S. 1976 — Beskorennoe termoburenie i ego primenenie dlja stroenija lednika Dzankuat — Mat. Glacjol. Issl. Kronika Obsuždenija, 28: 96—103.
9. Howorka F. 1965 — A steam — operated ice drill for the instalation of ablation stakes on glaciers — J. Glaciol., 41: 749—750.
10. Kasser P. 1960 — Ein leichter thermischer Eisbohrer als Hilfsgerät zur Installation von Ablationsstangen auf Gletschern — Geofis. pura appl., 45: 97—114.
11. Kudrjasov B. B., Bobin N. E., Sljusarev N. I., Stepanov G. K., Fisenko V. F., Čistjakov V. K. 1973 — Teorija i praktika burenija — protaivanija v Antarktide — Mat. Glacjol. Issl. Kronika Obsuždenija, 22: 71—76.
12. Kudrjasov B. B., Fisenko V. F. 1973 — K teorii burenija — protaivanija snežno-firnovych otloženij i ldov Antarktidy — Antarktika, Dokl. Kom. 12: 153—158.
13. Llibourty L. 1956 — Nieves y glaciares de Chile — Fundamentos de Glaciologica, Santiago de Chile — Editions de la Universidad de Chile, 471 pp.
14. Morev V. I. 1976 — Elektrotermobury dlja skvažin v lednikovom pokrove — Mat. Glacjol. Issl. Kronika Obsuždenija, 28: 118—120.
15. Paige R. A. 1969 — Drilling in snow, ice and frozen ground in Antarctica — Antarct. J.U.S., 4: 154—158.
16. Sekurov A. V. 1967 — Osobennosti razrabotki elektrotermoburogo kompleksa dlja burenija lda i rezultaty ego ispytanij v Mirnom v 1965/66 g. — Bjull. Sov. Antark. Eksp. 66: 59—62.
17. Shreve R. L. 1962 — Theory of performance of isothermal solid — nose hotpoints boring in temperature ice — J. Glaciol., 4: 151—160.
18. Shreve R. L., Kamb W. B. 1964 — Portable thermal core drill for temperate glaciers — J. Glaciol., 5: 113—117.
19. Stacey J. S. 1960 — A prototype hotpoint for thermal boring on the Athabaska Glacier — J. Glaciol., 3: 783—786.
20. Troickij L. S., Zinger E. M., Korjakin V. S., Markin V. A., Michalev V. I. 1975 — Oledenenie Spicbergena Svalbarda — Moskva, 276 pp.
21. Ueda H. T., Garfield D. E. 1969 — The USA CRREL drill for thermal coring in ice — J. Glaciol., 8: 311—314.
22. Zagorodnov V. S., Zotikov I. A., Barbat V. R., Michalev V. I. 1976 — O termoburenii na Lednike Obručeva — Mat. Glacjol. Issl. Kronika Obsuždenija, 28: 112—118.

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