Proc. NIPR Symp. Antarct. Geosci., 7, 115-121, 1994

PRELIMINARY RESULT FOR THE Sm-Nd WHOLE-ROCK AGE OF THE METAMORPHIC ROCKS FROM MOUNT PARDOE IN THE NAPIER COMPLEX, EAST ANTARCTICA

Yoshiaki TAINOSHO[1], Hiroo KAGAMI[2], Yuhei TAKAHASHI[3], Shigeru IIZUMI[4], Yasuhito OSANAI[5] and Noriyoshi TSUCHIYA[6]

[1]*Department of Natural Environment, Faculty of Human Development, Kobe University, Nada-ku, Kobe 657*
[2]*Institute for Study of the Earth's Interior, Okayama University, Misasa, Tohaku-gun, Tottori 682-01*
[3]*Geological Survey of Japan, 1-3, Higashi 1-chome, Tsukuba 305*
[4]*Department of Geology, Faculty of Science, Shimane University, Nishikawatsu, Matsue 690*
[5]*Department of Earth Sciences and Astronomy, Fukuoka University of Education, 729, Akama, Munakata 811-41*
[6]*Department of Resources Engineering, Faculty of Engineering, Tohoku University, Aoba, Aramaki, Aoba-ku, Sendai 980*

Abstract: The Sm-Nd whole rock isochron age was determined for metamorphic rocks from Mount Pardoe, Napier Complex. Acidic gneiss (orthopyroxene-mesoperthite-quartz gneiss), being one of the main representative metamorphic rocks, gave an age of 2516 ± 274 Ma with an initial $^{143}Nd/^{144}Nd$ ratio of 0.50914 ± 0.00021. εNd values normalized to 2516 Ma for individual acidic gneiss range from -3.7 to -7.0. This Sm-Nd whole-rock isochron age indicates a major period of equilibration of the isotopic system on a whole-rock scale at 2516 ± 274 Ma.

1. Introduction

The Napier Complex in East Antarctica consists of high-temperature granulite-facies rocks which are characterized by sapphirine-quartz and spinel-quartz mineral assemblages (SHERATON *et al*., 1987).

Most isotopic ages of the metamorphic rocks show Archaean age (-3100 Ma) for the peak of the granulite-facies metamorphism (BLACK and JAMES, 1983; BLACK *et al*., 1983a, 1986). However, the reliable Sm-Nd whole-rock isochron age, which is expected to suggest the age of granulite facies metamorphism, has not been determined so far.

This paper presents the Sm-Nd whole rock isochron age and the initial Nd isotopic composition for acidic gneisses from Mount Pardoe in the Napier Complex. The equilibration age of the acidic gneiss in the Sm-Nd whole-rock system will give the age of tectonothermal histories of the Napier Complex because acidic gneiss is the dominant rock-type.

2. Geologic Setting of Samples

Mount Pardoe is mainly underlain by pyroxene-quartz-feldspar gneiss. The gneiss is subdivided into potassic varieties (acidic gneiss, hereafter), which typically contain mesoperthite, and more calcic gneiss (charnockitic gneiss, hereafter) in which plagioclase is the predominant feldspar. The two major gneisses are not mutually exclusive because gradational varieties occur, and in many places the two types of gneisses are intimately interlayered. Garnet-bearing acidic gneiss occupies a minority of the space in the rocks and is commonly interlayered with the acidic gneiss. Impure quartzite is interlayered with garnet-bearing acidic gneiss. Lenses (1-2 m in length) of massive basic granulite are widespread in the acidic gneiss.

The Sm-Nd whole rock age determination was performed on the acidic gneisses. Localities of the rock samples for dating are shown in Fig. 1. The acidic gneiss is a dominant rock type on Mount Pardoe. It is composed mainly of mesoperthite, quartz and orthopyroxene with a small amount of garnet. Layering in the massive part is common. The acidic gneiss is generally medium-grained and granoblastic, but locally well-foliated. The acidic gneiss has a range of composition from granodioritic to granitic (Table 1). The charnockitic gneiss of tonalitic composition which is interlayered with the acidic gneiss contains calcic oligoclase or andesine antiperthite.

Eight samples for Nd isotope measurements were collected from one locality (21505) on Mount Pardoe (Fig. 2). Main constituent minerals and their modal composition of eight samples are shown in Table 2.

Four samples (21505B, 21505C, 21505D, 21505E) are acidic gneiss, three samples (21505A, 21505F, 21505F2) are garnet-bearing acidic gneiss and sample 21505G is impure quartzite. Samples 21505C, 21505D and 21505E occur as alternating beds of 10 to 30 cm thickness; 21505B occurs interlayered with garnet-bearing acidic gneiss.

The garnet-bearing acidic gneisses are well-layered. 21505F contains a large amount of garnet (6%) and a small amount of orthopyroxene (0.5%). Sample 21505F is poor in

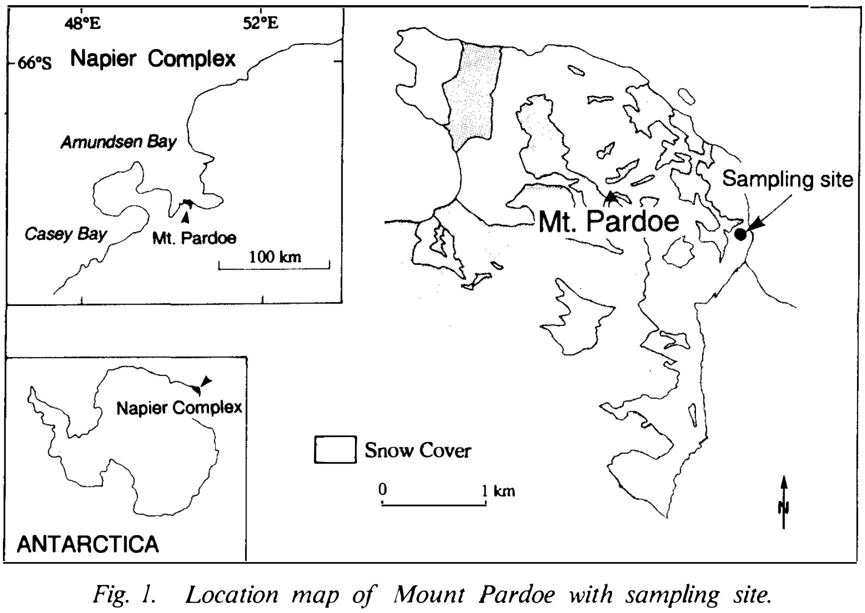

Fig. 1. Location map of Mount Pardoe with sampling site.

Table 1. Analytical results of the dated samples.

Sample	21505A	21505B	21505C	21505D	21505E	21505F	21505F2
SiO_2 wt%	78.39	66.72	74.37	73.21	76.44	81.24	80.27
TiO_2	0.32	0.95	0.10	0.33	0.59	0.09	0.30
Al_2O_3	11.15	8.88	11.85	12.77	11.13	9.45	10.03
Fe_2O_3*	1.08	10.12	6.92	2.20	2.72	0.66	2.22
MnO	0.01	0.15	0.02	0.03	0.02	0.02	0.02
MgO	0.63	6.09	0.18	4.23	0.43	0.41	1.48
CaO	1.24	3.21	2.39	1.15	2.23	1.23	1.20
Na_2O	3.89	2.25	2.90	2.82	3.14	2.47	2.60
K_2O	2.46	1.12	2.08	3.70	1.97	2.61	2.86
P_2O_5	0.04	0.11	0.02	0.05	0.07	0.02	0.03
Total	99.21	99.60	100.86	99.99	98.74	98.20	101.01

*Total iron as Fe_2O_3.

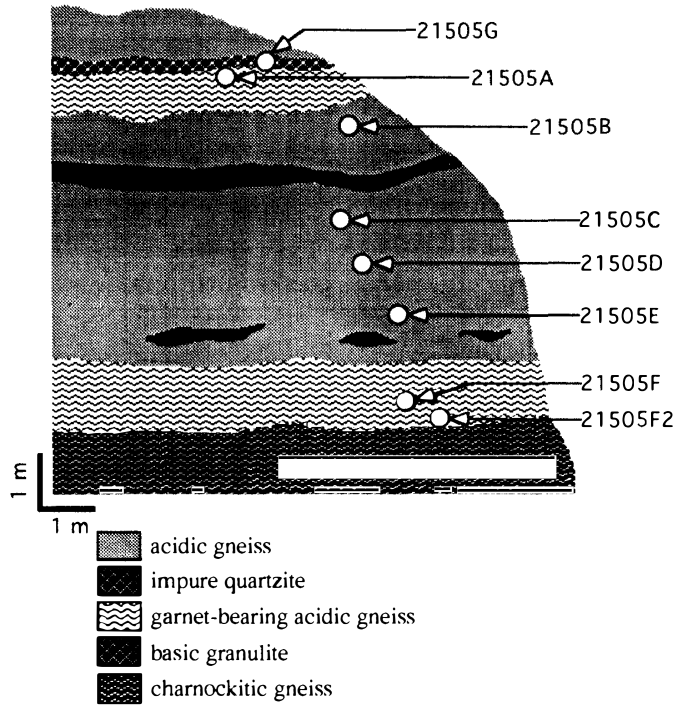

Fig. 2. Sampling points of acidic gneisses used for the whole-rock samples.

MgO and total Fe_2O_3. This sample has different lithologic character than the other acidic gneisses.

All of the acidic gneisses display granoblastic texture overprinted by intercrystalline deformation. Mesoperthite has recrystallized to plagioclase and K-feldspar. Orthopyroxene is partly replaced by actinolitic amphibole. Garnet coronas around orthopyroxene are developed as reaction rim. The effects of retrograde metamorphism are widespread in the acidic gneisses.

The impure quartzite is interlayered with the garnet-bearing acidic gneiss.

Table 2. Mineral assemblages and their modal composition in the acidic gneisses.

Sample number	Rock type	Mineral assemblages and their model volume %
21505A	garnet-bearing acidic gneiss	Qz (46.2)+Meso (46.1)+Opx (4.7)+Gt (3.0)
21505B	acidic gneiss	Meso (61.1)+Qz (31.9)+Opx (6.0)+Pl (1.0)
21505C	acidic gneiss	Meso (55.8)+Qz (40.4)+Opx (1.8)+Pl (1.8)+Gt (0.2)
21505D	acidic gneiss	Meso (52.7)+Qz (35.6)+Bi (5.1)+Opx (6.6)
21505E	acidic gneiss	Meso (57.1)+Qz (38.8)+Opx (4.1)
21505F	garnet-bearing acidic gneiss	Qz (49.8)+Meso (45.7)+Gt (6.0)+Opx (0.5)
21505F2	garnet-bearing acidic gneiss	Qz (47.6)+Meso (46.2)+Gt (3.2)+Opx (3.0)
21505G	quartzite	Qz (85.2)+Meso (14.2)+Opx (0.6)

Mineral abbreviations: Meso: mesoperthite, Qz: quartz, Opx: orthopyroxene, Gt: garnet, Pl: plagioclase, Bi: biotite

3. Analytical Methods

Whole-rock samples weighing 0.5-1 kg were crushed. Nd, Sm, Rb and Sr concentrations were determined by the isotope dilution method. The $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios were determined by MAT260 type mass spectrometer at the Institute for Study of the Earth's Interior, Okayama University. Mass spectrometric analyses follow the procedure of KAGAMI *et al.* (1987, 1989). All the $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios were normalized to $^{146}Nd/^{144}Nd=0.7219$ and $^{86}Sr/^{88}Sr=0.1194$. $^{143}Nd/^{144}Nd$ results are reported relative to $^{143}Nd/^{144}Nd=0.512640$ for BCR-1. Sr isotope ratios for NBS987 were measured twice during this study, with a mean ratio of 0.710238 ± 0.000009 (2σ). We estimate an error of 0.5% for the Sm/Nd ratios of each sample based on reproducibility of the data. We used the following CHUR parameter for calculation of initial εNd values: $^{143}Nd/^{144}Nd$ (present)=0.512638, $^{147}Sm/^{144}Nd$ (present)=0.1966, $\lambda^{147}Sm=6.54\times10^{-12}y^{-1}$, $^{87}Sr/^{86}Sr$ (present)=0.7045, $^{87}Rb/^{86}Sr$ (present)=0.0827, $\lambda^{87}Rb=1.42\times10^{-11}y^{-1}$.

SiO_2 and some other element compositions were determined with XRF at Shimane University.

4. Results and Discussion

Seven samples of the acidic gneiss and one impure quartzite were used for analyses. Sm/Nd analytical data for whole-rock samples of this outcrop are given in Table 3 and are plotted in an isochron diagram (Fig. 3). All seven samples except for 21505F define an isochron of 2516 ± 274 Ma with an initial $^{143}Nd/^{144}Nd$ ratio of 0.50914 ± 0.00021. 21505F is not plotted in this isochron, because 21505F is distinctively different from the lithologic character of other acidic gneisses.

Similar Sm-Nd whole-rock isochron ages (2458 ± 61 Ma) have been obtained from Tonagh Island (10 km north of Mount Pardoe) (Owada *et al.*, 1993, 1994). MCCULLOCH and BLACK (1984) reported an Sm-Nd whole-rock age (2410 ± 100 Ma) from Mount Sones. An Rb-Sr whole- rock age of 2463 ± 35 Ma has been reported from the Fyfe Hills region

Table 3. Sm-Nd analytical data for the acidic gneisses.

Sample	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	T_{DM}
21505A	2.67	17.5	0.0922	0.510617 ± 0.000012	3160 Ma
21505B	8.00	31.0	0.1562	0.511728 ± 0.000009	3750 Ma
21505C	1.25	9.2	0.0826	0.510527 ± 0.000018	3030 Ma
21505D	15.10	72.5	0.1258	0.511271 ± 0.000014	3240 Ma
21505E	1.92	10.2	0.1137	0.510914 ± 0.000015	3390 Ma
21505F	2.58	12.5	0.1242	0.510976 ± 0.000012	3680 Ma
21505F2	1.91	15.5	0.0743	0.510421 ± 0.000012	2970 Ma
21505G	1.24	5.7	0.1324	0.511388 ± 0.000013	3290 Ma

Model age calculation (T_{DM}) parameters follow McCulloch and Black (1984).

$$T^{Nd}_{DM} = \frac{1}{\lambda}\ln\left[1 + \frac{0.513153-(^{143}Nd/^{144}Nd)^{sample}}{0.2136-(^{147}Sm/^{144}Nd)^{sample}}\right],\ \lambda = 6.54 \times 10^{12} y^{-1}.$$

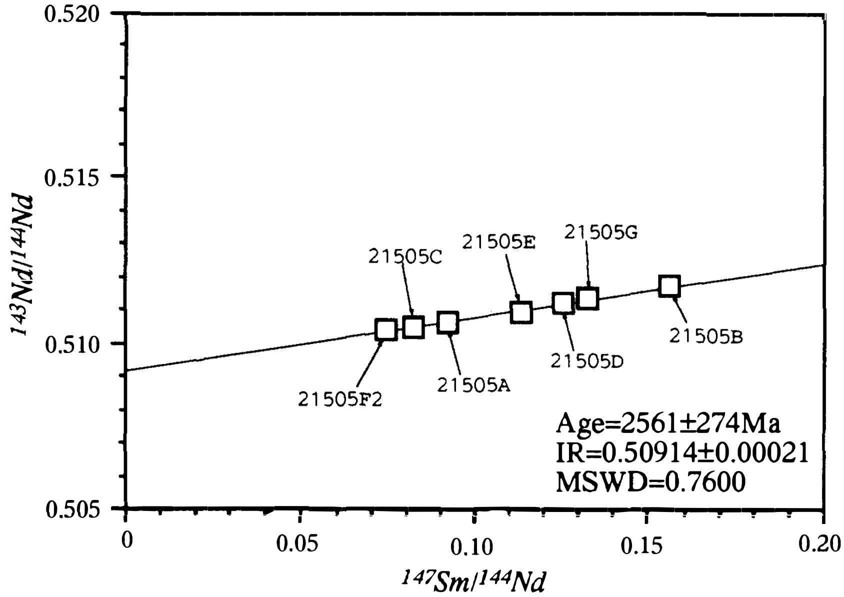

Fig. 3. Sm-Nd whole rock isochron diagram for the acidic gneisses from Mount Pardoe.

(Black *et al.*, 1983b). Thus, many ages are about 2450-2500 Ma elsewhere in the Napier Complex. These Sm-Nd and Rb-Sr age data indicate that there was major metamorphism about 2450-2500 Ma (Black and James,1979 ; Black *et al.*, 1983b ; McCulloch and Black, 1984 ; Black and McCulloch, 1987 ; Sheraton *et al.*, 1987 ; Owada *et al.*, 1994). We consider that the Sm-Nd whole-rock isochron age for the acidic gneiss on Mount Pardoe indicates a major period of equilibration of the isotopic system on a whole rock at about 2500 Ma, that is, a significant thermal tectonic event occurred at that time elsewhere in the Napier Complex (Black *et al.*, 1983a).

The $^{143}Nd/^{144}Nd$ ratio (0.50914 ± 0.00021) of the acidic gneiss is slightly high compared with that of the basic gneiss on Tonagh Island (0.50897 ± 0.00004, Owada *et al.*, 1994). The εNd values normalized to 2516 Ma of individual acidic gneiss range from -3.7 to -7.0. These εNd values are low compared with that of CHUR. The acidic gneisses

Table 4. Rb-Sr analytical data for the acidic gneisses.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
21505A	23.6	57.7	1.190	0.761193
21505B	29.2	96.6	0.897	0.742342
21505E	28.1	115.1	0.707	0.736653
21505F	45.2	56.9	2.321	0.804776

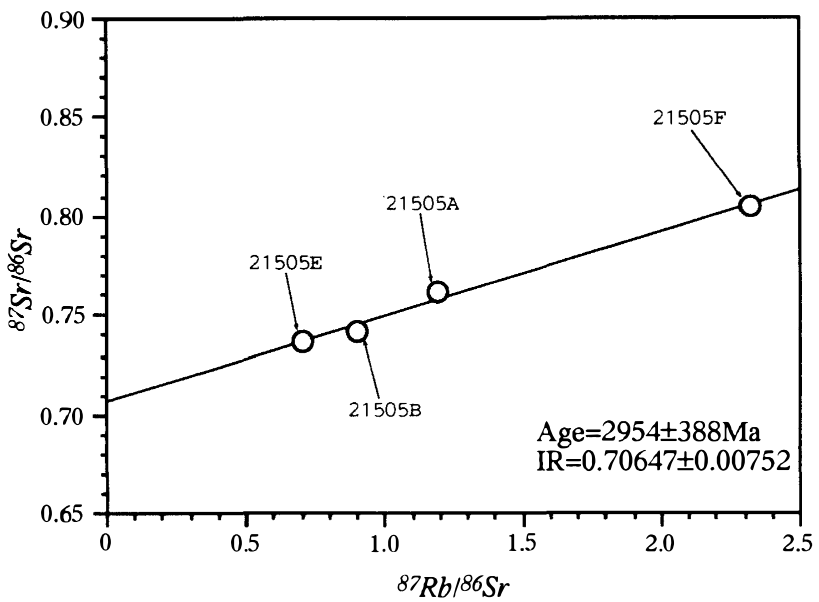

Fig. 4. Rb-Sr whole rock isochron diagram for the acidic gneisses from Mount Pardoe.

present a relatively wide range of εNd values and are not plotted on the CHUR evolution curve. The large negative εNd values suggest that the acidic gneisses had a complicated crustal history. Furthermore, the samples plotted on the 2516±274 Ma isochron show model age $T_{DM}=2970$ to 3750 Ma (Table 3), suggesting that the model age of *c.* 3200 Ma indicates formation of acidic gneisses derived from the initial crust in the Mount Pardoe region.

Rb-Sr isotope analyses are made on four acidic gneisses (21505A, 21505B, 21505E, 21505F). These isotopic results are listed in Table 4. Whole-rock data are plotted on an isochron diagram but the data are slightly scattered (Fig. 4). Four samples gave an age of 2954±388 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70647±0.00752 (Fig. 4). However, they did not yield a well defined isochron age.

Retrograde metamorphism is common in the acidic gneisses. Mesoperthite has recrystallized to plagioclase and K-feldspar. Garnet coronas around pyroxene are developed in the garnet-bearing acidic gneiss. We can infer that the Rb-Sr age (2954±388 Ma) for the acidic gneisses might be due to Rb and Sr loss by secondary effects caused by the retrograde metamorphism. The Rb-Sr isotope data for the acidic gneisses indicate a major period of re-equilibration of the isotopic system on a whole rock. It seems that the retrogressive metamorphism had a great effect on the Rb-Sr whole-rock system compared with the Sm-Nd whole-rock system.

5. Summary

The acidic gneiss from Mount Pardoe, Napier Complex, gave an Sm-Nd age of 2516± 274 Ma with low initial $^{143}Nd/^{144}Nd$ ratio (0.50914±0.00021). This Sm-Nd whole-rock isochron age may indicate significant a tectonothermal event of the equilibration of the isotopic system.

Acknowledgments

We wish to express our sincere thanks to members of JARE-31, for their kind support during the field work. We also wish to thank Dr. K. SHIRAISHI for valuable discussion on the field occurrence.

References

BLACK, L.P. and JAMES, P.R. (1979): Preliminary isotopic ages from Enderby Land, Antarctica (abstract). J. Geol. Soc. Aust., **26**, 266-267.

BLACK, L.P. and JAMES, P.R. (1983): Geological history of the Napier Complex of Enderby Land. Antarctic Earth Science, ed. by R.L. Oliver. Canberra, Aust. Acad. Sci., 11-15.

BLACK, L.P. and MCCULLOCH, M.T. (1987): Evidence for isotopic equilibration of Sm-Nd whole-rock system in early Archaean crust of Enderby Land, Antarctica. Earth Planet. Sci. Lett., **82**, 15-24.

BLACK, L.P., JAMES, P.R. and HARLEY, S. (1983a): Geochronology and geological evolution of metamorphic rocks in the Field Islands area, Antarctica. J. Metamorph. Geol., **1**, 277-303.

BLACK, L.P., JAMES, P.R. and HARLEY, S.L. (1983b): The geochronology, structure and metamorphism of early Archaean rocks at Fyfe Hills, Enderby Land, Antarctica. Precambrian Res., **21**, 197-222.

BLACK, L.P., WILLIAMS, I.S. and COMPSTON, W. (1986): Four zircon ages from one rock: The history of a 3930 Ma-old granulite from Mount Sones, Antarctica. Contrib. Mineral. Petrol., **94**, 427-437.

KAGAMI, H., IWATA, M., SANO, S. and HONMA, H. (1987): Sr and Nd isotopic compositions and Rb, Sr, Sm and Nd concentrations of standard samples. Tech. Rep. ISEI Okayama Univ., Ser. B, **4**, 16 p.

KAGAMI, H., YOKOSE, H. and HONMA, H. (1989): $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of GSJ rock reference samples; JB-1a, JA-1 and JG-1a. Geochem. J., **23**, 209-214.

MCCULLOCH, M.T. and BLACK, L.P. (1984): Sm-Nd isotopic systematics of Enderby Land granulites and evidence for the redistribution of Sm and Nd during metamorphism. Earth Planet. Sci. Let., **71**, 46-58.

OWADA, M., OSANAI, Y. and KAGAMI, H. (1993): Higashi-Nankyoku Napia Gantai, enki-sei henseigan no Sm-Nd nendai (Sm-Nd age of basic metamorphic rocks from the Napier Complex). Dai-13-kai Nankyoku Chigaku Shinpojiumu Puroguramu. Kôen Yôshi (Prog. Abstr. 13th Symp. Antarct. Geosci.). Tokyo, Natl Inst. Polar Res., 18.

OWADA, M., OSANAI, Y. and KAGAMI, H. (1994): Isotopic equilibration age of Sm-Nd whole-rock system in the Napier Complex (Tonagh Island), East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **7**, 122-132.

SHERATON, J.W., TINGEY, R.J., BLACK, L.P., OFFE, L.A. and ELLIS, D.J. (1987): Geology of Enderby Land and Western Kemp Land, Antarctica. Aust. Bur. Miner. Resour. Geol. Geophys., Bull., **223**, 51 p.

(Received April 5, 1994; Revised manuscript received June 25, 1994)