J. Earth Planet. Sci. Nagoya Univ., Vol. 46, 49 to 56, 1999 [On-line revision 4]

Computer program for the CHIME age calculation

Takenori, KATO, Kazuhiro, SUZUKI and Mamoru ADACHI

**Department of Earth and Planetary Sciences, Graduate School of Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8602, Japan*

(Received October 19, 1999 / Accepted November 11, 1999)

ABSTRACT

A computer program for the CHIME age calculation is presented. By using reiteration procedures, the program saves significantly the time taken to estimate the isochron age from a dataset of ThO_2, UO_2 and PbO or Th, U and Pb analyses of Th- and/or U-bearing minerals. The program works under FreeBSD/i386 version 2.2.8 or later versions on IBM–PC and compatible computers and is available from http://www.nendai.nagoya-u.ac.jp/gsd/CHIME/ through the Internet.

INTRODUCTION

The CHIME (Chemical Th-U-total Pb Isochron Method) dating method is based on the electron microprobe analysis of Th- and/or U-bearing minerals (Suzuki et al., 1991; Suzuki and Adachi, 1991a, b). The method offers a high spatial resolution and is applicable to subgrain dating of monazite, zircon, polycrase-euxenite, xenotime and allanite. Various studies using the CHIME method have been successful in revealing complex histories of orogenic belts (Suzuki et al., 1991; Suzuki and Adachi, 1991a, 1991b; Adachi and Suzuki, 1992; Adachi et al., 1992; Suzuki et al., 1992; Adachi and Suzuki, 1993; Enami et al., 1993; Morishita and Suzuki, 1993; Suzuki and Adachi, 1993; Adachi and Suzuki, 1994; Adachi et al., 1994; Suzuki and Adachi, 1994; Suzuki et al., 1994; Suzuki et al., 1994; Adachi and Suzuki, 1995; Khan et al., 1995; Morishita and Suzuki 1995; Suzuki et al., 1995; Asami et al., 1996; Cho et al., 1996; Nakai and Suzuki, 1996; Suzuki et al., 1996; Suzuki et al., 1996; Suzuki et al., 1996; Asami et al., 1997; Ito et al., 1997; Kato et al., 1997; Kim et al., 1997; Tadesse et al., 1997 Asami et al., 1998; Bindu et al., 1998; Chang et al., 1998; Suzuki and Adachi, 1998; Suzuki et al., 1998;). Recently, the chemical Th-U-total Pb dating using an electron microprobe has been done by many authors in addition to the originator's group (Montel et al., 1996; Rhede et al., 1996; Cocherie et al., 1998; Braun et al., 1998; Williams et al., 1999).

Although conventional chemical Th-U-total Pb dating methods do not provide information about discordancy in the Th-U-Pb system, the CHIME method has the advantage of lead loss detection and common lead estimation by means of an isochron method. However, the calculation of isochron from the data set of EPMA Th, U and Pb analysis is not easy without computer programs, because the system contain three different decay chains. The original CHIME age calculation program runs on only NEC PC–9801 series and its compatible computers. Therefore, it is hard to use the program for many geoscientists in the world. We here present an alternative com-

puter program to calculate CHIME ages for IBM-PC and compatible computers. This paper introduces the outline of the computer program and compares its results with that from the originators' program.

THE CHIME AGE CALCULATION

Details of the CHIME age calculation have been reported in Suzuki and Adachi (1991a, 1991b, 1994). From the concentrations of U, Th and Pb, apparent age t is calculated from:

$$\frac{PbO}{W_{Pb}} = \frac{ThO_2}{W_{Th}}\{\exp(\lambda_{232}t) - 1\} + \frac{UO_2}{W_U}\left\{\frac{\exp(\lambda_{235}t) + 137.88\exp(\lambda_{238}t)}{138.88} - 1\right\} \quad (1)$$

where

PbO: concentration of PbO
ThO_2: concentration of ThO_2
UO_2: concentration of UO_2
W_{Pb}: molecular weight of Pb (= 224 for ThO_2-rich minerals and = 222 for UO_2-rich minerals),
W_{Th}: molecular weight of Th (= 264)
W_U: molecular weight of U (= 270)
λ_{232}: decay constants (= 4.9475×10^{-11}/y, Steiger and Jäger, 1977)
λ_{235}: decay constants (= 9.8485×10^{-10}/y, Steiger and Jäger, 1977)
λ_{238}: decay constants (= 1.55125×10^{-10}/y, Steiger and Jäger, 1977)

In the calculation for ThO_2-rich mineral, the apparent amount of total ThO_2 (ThO_2^*) is given by:

$$ThO_2^* = ThO_2 + \frac{UO_2 \cdot W_{Th}}{W_U\{\exp(\lambda_{232}t) - 1\}} \bullet \left\{\frac{\exp(\lambda_{232}t) + 137.88\exp(\lambda_{238}t)}{138.88} - 1\right\} \quad (2)$$

and in a calculation for UO_2-rich mineral, the apparent amount of total UO_2 (UO_2^*) is given by:

$$UO_2^* = UO_2 + \frac{138.88ThO_2 \cdot W_U\{\exp(\lambda_{232}t) - 1\}}{W_{Th}\{\exp(\lambda_{235}t) + 137.88\exp(\lambda_{238}t) - 138.88\}} \quad (3)$$

The relationship between PbO and ThO_2^* or PbO and UO_2^* values are given by:

$$\begin{cases} PbO = m \cdot ThO_2^* + b & (ThO_2\text{-rich mineral}) \\ PbO = m \cdot UO_2^* + b & (UO_2\text{-rich mineral}) \end{cases} \quad (4)$$

where m is a function of T. Isochron procedure gives estimated values for m and

b and estimated ages and the amount of initial PbO can be calculated from them. Recalculation of ThO_2^* or UO_2^* with estimated T and isochron procedure provide revised estimates. Reiteration of this procedure provides reliable estimate of age and initial PbO.

COMPUTER PROGRAM

The computer program described in this paper performs reiteration of the isochron procedure described above. Isochron procedure is based on York (1966).

The computer program is available from http://www.nendai.nagoya-u.ac.jp/gsd/CHIME/ through the Internet. The binary file for FreeBSD/i386 2.2.8 and later versions is provided.

(Comparison with the originators' program)

Even though we consider that the present program in this paper is reliable, we compare its results with that by the originators' program. Published EPMA analysis of monazite and zircon grains (Suzuki and Adachi, 1994) are used in this comparison (Table 1). For the monazite grain, the program in this paper gives:

$$253 \pm 24\text{Ma (MSWD} = 0.16)$$

and the originators' program gives:

$$253 \pm 24\text{Ma (MSWD} = 0.17)$$

For zircons grain, the program in this paper gives:

$$2036 \pm 58\text{Ma (MSWD} = 0.07)$$

and the originators' program gives:

$$2036 \pm 57\text{Ma (MSWD} = 0.07)$$

These calculations clearly indicate that the results by the present program conforms to that by the originators' program.

(File Format)

A file read by the program is a text file. Each line has following seven fields:

'Spot ID':String for identification
ThO_2: ThO_2 in wt.%
error of ThO_2:relative analytical error of ThO_2 in %
UO_2: UO_2 in wt.%
error of UO_2:relative analytical error of UO_2 in wt.%
PbO: PbO in wt.%
error of PbO:relative analytical error of PbO in wt.%

Table 1: Analytical data of monazite and zircon grains from the Hida gneiss on Oki-Dogo Island (taken from Suzuki and Adachi 1994)

Spot ID	ThO_2 wt.%	error %	UO_2 wt.%	error %	PbO wt.%	error %
Monazite grain M71 from sample 0304						
M71-01	7.25	1	0.832	5	0.106	5
M71-02	6.88	1	0.672	5	0.092	10
M71-03	6.69	1	0.349	5	0.085	10
M71-04	6.79	1	1.41	2	0.123	5
M71-05	7.02	1	0.458	5	0.089	10
M71-06	7.21	1	1.13	2	0.115	5
M71-07	7.92	1	0.560	5	0.108	5
M71-08	7.08	1	0.405	5	0.087	10
M71-09	7.11	1	0.668	5	0.098	10
M71-10	7.80	1	1.499	2	0.132	5
M71-11	7.77	1	1.816	2	0.146	5
M71-12	7.28	1	1.299	2	0.122	5
M71-13	6.80	1	0.929	5	0.100	5
M71-14	7.14	1	0.447	2	0.092	10
Zircon grain Z209 from sample 0304						
Z209-1	0.083	10	0.186	10	0.069	10
Z209-2	0.155	10	0.187	10	0.077	10
Z209-3	0.181	10	0.314	5	0.119	5
Z209-4	0.302	5	0.392	5	0.159	5
Z209-5	0.143	10	0.112	10	0.050	10
Z209-6	0.188	10	0.321	5	0.121	5
Z209-7	0.093	10	0.163	5	0.060	10
Z209-8	0.544	5	0.399	5	0.186	5

The spot ID field should not contain white space (space and tab). Each field should be separated by white spaces like:

M01-01 2.20 1.1 0.228 3.8 0.069 14.6

No comment line should be in a file.

The above example shows that (1) spot ID is ‘M01-01’, (2) ThO_2 = 2.20 wt.% and its relative analytical error is 1.1%, (3) UO_2 = 0.228 wt.% and its relative analytical error is 3.8% and (4) PbO = 0.069 wt.% and its relative analytical error is 14.6%. If command line option `-m' is set (see bellow), it shows that (1) spot ID is ‘M01-01’, (2) Th = 2.20 wt.% and its relative analytical error is 1.1%, (3) U = 0.228 wt.% and its relative ana-

ytical error is 3.8% and (4) Pb = 0.069 wt.% and its relative analytical error is 14.6%.

(Command line options)

The program has following command line options:

- -u UO_2-rich mineral mode. Use this option when you calculate the CHIME age of UO_2-rich mineral (e.g. zircon).
- -t ThO_2-rich mineral mode. Use this option when you calculate the CHIME age of ThO_2-rich mineral (e.g. monazite).
- -v displays analysis results, apparent ages and RO*2for each spot.
- -f*file* tells file for input. If this option is not specified, the program read data from standard input.
- -m assumes that concentrations are amounts of metals instead of oxides. Default is oxide-mode.

One of -u and -t options is mandatory. When the option `-m' is specified, amounts of PbO, ThO_2 and UO_2 are calculated by

$$\begin{aligned} PbO &= \begin{cases} PbO \cdot \dfrac{224}{208} & (ThO_2\text{–mineral mode}) \\ PbO \cdot \dfrac{222}{206} & (UO_2\text{–mineral mode}) \end{cases} \\ ThO_2 &= Th \cdot \frac{264}{232} \\ UO_2 &= U \cdot \frac{270}{238} \end{aligned} \tag{5}$$

When the EPMA analysis of zircon is stored in the file `zircon', typing

```
chime -u -f zircon
```

gives the CHIME age, error and MSWD (Fig. 1). When the EPMA analysis of monazite is stored in the file `monazite' typing

```
chime -vt -f monazite
```

gives the CHIME age, error, MSWD and spot ID, concentrations and analytical error

```
% chime -u -f zircon
Number of data point: 8          MSWD=0.071520
   Age / Ma = 2035.680177   +/-   58.355947
inclination = 0.341159   +/-   0.012659
  intercept = -0.002484   +/-   0.003832
```

Fig. 1: Calculation result using the present program for the zircon.

```
% chime -vt -f monazite
Number of datapoint:14              MSWD=0.157437
   Age / Ma  = 253.156361  +/-  23.731568
inclination = 0.010694  +/-  0.001009
  intercept = -0.000901 +/-  0.010499

Spot No. ThO2   Error UO2   Error PbO   Error Age  RO2*
  M71-01  7.2500 1.0 0.8320 5.0 0.1060 5.0 252  9.9482
  M71-02  6.8800 1.0 0.6720 5.0 0.092010.0 241  9.0593
  M71-03  6.6900 1.0 0.3490 5.0 0.085010.0 257  7.8218
  M71-04  6.7900 1.0 1.4100 2.0 0.1230 5.0 256 11.3626
  M71-05  7.0200 1.0 0.4580 5.0 0.089010.0 248  8.5053
  M71-06  7.2100 1.0 1.1300 2.0 0.1150 5.0 250 10.8746
  M71-07  7.9200 1.0 0.5600 5.0 0.1080 5.0 263  9.7361
  M71-08  7.0800 1.0 0.4050 5.0 0.087010.0 245  8.3934
  M71-09  7.1100 1.0 0.6680 5.0 0.098010.0 250  9.2763
  M71-10  7.8000 1.0 1.4990 2.0 0.1320 5.0 247 12.6613
  M71-11  7.7700 1.0 1.8160 2.0 0.1460 5.0 253 13.6593
  M71-12  7.2800 1.0 1.2990 2.0 0.1220 5.0 251 11.4927
  M71-13  6.8000 1.0 0.9290 5.0 0.1000 5.0 241  9.8127
  M71-14  7.1400 1.0 0.4470 2.0 0.092010.0 254  8.5896
```

Fig. 2: Calculation result using the present program for the monazite. Spot ID, concentrations and analytical erros of oxide, apparent age and amount of total oxide (RO_2^*) of each spot are also shown since '-v' option is specified.

of oxides, apparent age and ThO^*_2 or UO^*_2 for each spot (Fig. 2).

ACKNOWLEDGMENTS

Dr. R. Metralfe of Tono Geoscience Center of Japan Nuclear Cycle Development Institute reviewed the manuscript and provided constructive comments.

REFERENCES

Adachi, M., Kojima, S., Wakita, K., Suzuki, K. and Tanaka, T. (1992) Transect of central Japan: from Hida to Shimanto. *29th IGC Field Trip Guide Book*, **1**,143-178.

Adachi, M. and Suzuki, K. (1992) A preliminary note on the age of detrital monazites and zircons from sandstones in the Upper Triassic Nabae Group, Maizuru terrane. *Mem. Geol. Soc. Japan*, **38**, 111-120.

Adachi, M. and Suzuki, K. (1993) Were Precambrian gneiss clasts in the Kamiaso conglomerate derived from the eastern Korean Peninsula? *Bull. Nagoya Univ. Furukawa Mus.*, **9**, 25-47.

Adachi, M. and Suzuki, K. (1994) Precambrian detrital monazites and zircons from Jurassic turbidite sandstones in the Nomugi area, Mino terranes. *J. Earth Planet. Sci., Nagoya Univ.*, **41**, 33-43.

Adachi, M. and Suzuki, K. (1995) Re-examination of pre-Cretaceous basement Rocks in Korea by CHIME geochronology. *J. Geography*, **104**, 589-591 (in Japanese with English abstract).

Adachi, M., Suzuki K., Yogo, S. and Yoshida, S. (1994)The Okuhinotsuchi granitic mass in the South Kitakami terrane: pre-Silurian basement or Permian intrusives. *J. Min. Pet. Econ. Geol.*, **89**, 21-36.

Asami, M., Suzuki, K. and Adachi, M. (1996) Monazite ages by the chemical Th–U–total Pb isochron method for pelitic gneisses from the eastern Sor Rondane Mountains, East Antarctica. *Proc. NIPR Symp. Antarct. Geosci.*, **9**, 49-64.

Asami, M., Suzuki, K. and Adachi, M. (1997) Th, U and Pb analytical data and CHIME dating of monazites from metamorphic rocks of the Yayner, Lutzow-Holm, Yamato-Belgica and Sor Rondane Complexes, East Antarctica. *Proc. NIPR Symp. Antarct. Geosci.*, **10**, 130-152.

Asami, M., Suzuki, K., Grew, E.S. and Adachi, M. (1998) CHIME ages for granulites from the Napier Complex, East Antarctica. *Proc. NIPR Symp. Antarct. Geosci.*, **11**, 172-199.

Bindu, R. S., Suzuki, K., Yoshida, M. and Sntosh, M. (1998)The first report of CHIME monazite age from the South Indian granulite terrain. *Cur. Sci.*, **74**, 852-858.

Braun, I., Montel, J. M. and Nicollet, C. (1998) Electron microprobe dating of monazites from high-grade gneisses and pegmatites of the Kerala Khondalite Belt, souther India. *Chem. Goel.*, **146**, 65-85.

Chang, K. H., Lee, Y. J., Suzuki, K. and Park, S. O. (1998) Zircon morphology, CHIME age and geologic siginificance of Kusandong tuff (Cretaceous). *J. Geol. Soc. Korea*, **34**, 333-342 (in Korean with English abstract).

Cho, D. K., Suzuki, K., Adachi, M. and Chwae, U. (1996) CHIME age determination of monazite in metamorphic rocks and granite from Gyeonggi Massif, Korea. *J. Earth Planet. Sci., Nagoya Univ.*, **43**, 43-65.

Cocherie, A., Legendre, O., Peucat, J. J. and Kouamelan, A. N. (1998) Geochronology of polygenetic monazites constrained by in situ electron microprobe Th–U–total lead determination: Implications for lead behavior in monazite. *Geochim. Cosmochim. Acta*, **62**, 2475-2497.

Enami, M., Suzuki, K., Zhai, M. and Zheng, X. (1993) The chemical Th–U–total Pb isochron ages of Jiaodong and Jiaonan metamorphic rocks in the Shandong Peninsula, eastern China. *Island Arc*, **2**, 104-113.

Ito, M., Suzuki, K. and Yogo, S. (1997) Cambrian granulite to upper amphibolite facies metamorphism of post-797 Ma sediments in Madagascar. *J. Earth Planet. Sci., Nagoya Univ.*, **44**, 89-102.

Kato, T., Suzuki, K., Morishita, T and Yonezawa, C. (1997) CHIME ages of zircons in granitic gneiss and granite from Samilpo, southeastern Democratic People's Republic of Korea. *J. Earth Planet. Sci., Nagoya Univ.*, **44**, 61-69.

Khan, I. H., Suzuki, K., Shibata, K. and Adachi, M. (1995) Late Permian CHIME ages of the Hida Gneiss and early Triassic age of the Mizunashi Granite in the Amo area of the Hida terrane, central Japan. *J. Earth Planet. Sci., Nagoya Univ.*, **42**, 31-43.

Kim, B. C., Choi, S. J., Suzuki, K., Adachi, M., Obayashi, T. and Yu, K. M. (1997) Middle Precambrian, Late Permian and Middle Jurassic provenance for Cretaceous sandstone in the Southeast Youngdong basin, Korea: CHIME geochronology of detrital monazites, *Geoscience J.*, **1**, 37-49.

Montel, J. M., Foret, S., Veschambre, M. Nicollet, C. and Provost, A. (1996) Electron microprobe dating of monazite. C*hem. Geol.*, **131**, 37-53.

Morishita, T. and Suzuki, K. (1993) XRF analyses of the Mitsuhashi granite in the Shitara area, Aichi prefecture. *Bull. Nagoya Univ. Furukawa Museum*, **9**, 77-90 (in Japanese with English abstract).

Morishita, T. and Suzuki, K. (1995) CHIME ages of monazite from the Shinshiro Tonalite of the Ryoke belt in the Mikawa area, central Japan. *J. Earth Planet. Sci, Nagoya Univ.*, **42**, 45-53.

Nakai, Y. and Suzuki, K. (1996) CHIME monazite ages of the Kamihara Tonalite and the Tenryukyo Granodiorite in the eastern Ryoke belt of central Japan. *J. Geol. Soc. Japan*, **102**, 431-439.

Rhede, D., Wendt, I. and F"orster, H.J. (1996)A three-dimensional method for calculating independent chemical U/Pb- and Th/Pb-ages of accessory minerals. *Chem. Geol.*, **130**, 247-253.

Steiger, R. H. and Jäger, E. (1977)Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology. *Earth Planet. Sci. Lett.*, **36**, 359-362.

Suzuki, K. and Adachi, M. (1991a) Precambrian provenance and Silurian metamorphism of the Tsubonosawa paragneiss in the South Kitakami terrane, Northeast Japan. Geochem. J., 25,

357-376.

Suzuki, K. and Adachi, M. (1991b) The chemical Th–U–total Pb isochron ages of zircon and monazite from the Gray Granite of the Hida terrane, Japan. *J. Earth Sci., Nagoya Univ.*, **38**, 11-37.

Suzuki, K. and Adachi, M. (1993) 240 Ma CHIME ages of monazite and zircon from the Hirasawa granitic mass in the South Kitakami terrane. *J. Earth Planet. Sci., Nagoya Univ.*, **40**, 1-16.

Suzuki, K. and Adachi, M. (1994) Middle Precambrian detrital monazite and zircon from the Hida gneiss on Oki-Dogo Island, Japan: their origin and implication for the correlation of the basement of Southwest Japan and Korea. *Tectonophysics*, **235**, 277-292.

Suzuki, K. and Adachi, M. (1998) Uplift history of the high T / P Ryoke metamorphic belt, Southwest Japan: constraints from CHIME monazite ages of gneisses and granitoids. *J. Metamorphic Geol.*, **16**, 23-37.

Suzuki, K., Adachi, M. and Kajizuka, I. (1994)Electron microprobe observations of Pb diffusion in metamorphosed detrital monazites. *Earth Planet. Sci. Lett.*, **128**, 391-405.

Suzuki, K., Adachi, M. and Nureki, T. (1996)CHIME age dating of monazites from metamorphic rocks and granitic rocks of the Ryoke belt in the Iwakuni area, Southwest Japan. *Island Arc*, **5**, 43-55.

Suzuki, K, Adachi, M., Sango, K and Chiba, H. (1992)Chemical Th–U–total Pb isochron ages of monazites and zircons from the Hikami Granite and "Siluro-Devonian" clastic rocks in the South Kitakami Terrane. *J. Mineral. Petrol. Econ. Geol.*, **87**, 330-349. (in Japanese with English Abstract)

Suzuki, K, Adachi, M. and Tanaka, T. (1991) Middle Precambrian provenance of Jurassic sand stone in the Mino terrane, central Japan: Th–U–total Pb evidence from an electron micro probe monazite study. *Sed. Geol.*, **75**, 141-147.

Suzuki, K., Hayama, Y., Inomata, M. and Genyao, W. U. (1996) CHIME ages of Cretaceous gneissic granitoids in the Pingtan - Dongshan belt, Fujian, China. *Geotec. Metallog.*, **20**, 127-131.

Suzuki, K., Morishita, T., Kajizuka, I., Nakai, Y., Adachi, M. and Shibata, K. (1994) CHIME ages of monazites from the Ryoke metamorphic rocks and some granitoids in the Mikawa-Tono area, central Japan. *Bull. Nagoya Univ. Furukawa Museum*, **10**, 17-38 (in Japanese with English Abstract).

Suzuki, K., Nakazaki, M. and Adachi, M. (1998) An 86±5 Ma CHIME age for the lowest welded tuff sheet of the Nohi Rhyolite, central Japan. *J. Earth Planet. Sci., Nagoya Univ.*, **45**, 17-27.

Suzuki, K., Nasu, T. and Shibata, K. (1995) CHIME monazite ages of the Otagiri and Ichida Granites in the Komagane area, Nagano Prefecture. *J. Earth Planet. Sci., Nagoya Univ.*, **42**, 17-30.

Suzuki, K., Yoshida, H. and Amano, K. (1996) CHIME dating of monazite from pelitic hornfels of the Kurihashi Granodiorite, Kitakami Mountains. *J. Earth Planet. Sci. Nagoya Univ.*, **43**, 17-26.

Taddesse, T., Suzuki, K. and Hoshino, M. (1997)Chemical Th–U–total Pb isochron age of zircon from the Mereb Granite in nouthern Ethiopia. *J. Earth Planet Sci., Nagoya Univ.*, **44**, 21-27.

Williams, M., Jercinovic, M. and Terry, M. (1999)Age mapping and dating of monazite on the electron microprobe: Deconvoluting multistage tectonic histories. *Geology*, **27**, 1023-1026.

York, D. (1966) Least-squares fitting of a straight line. *Can. J. Phys.*, **44**, 1079-1086.