Sedimentary Geology, 55 (1988) 319–322
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

THE CIW INDEX: A NEW CHEMICAL INDEX OF WEATHERING *

LUC HARNOIS

Department of Earth Sciences, Carleton University, Ottawa, Ont. K1S 5B6 (Canada)

(Received July 20, 1987; accepted for publication October 6, 1987)

ABSTRACT

Harnois, L., 1988. The CIW index: A new chemical index of weathering. Sediment. Geol., 55: 319–322.

A new chemical index of weathering that can be applied to modern soils and Precambrian paleosols is proposed:

$CIW = [Al_2O_3/(Al_2O_3 + CaO + Na_2O)] \times 100$ (molecular proportions)

The value of this index increases as the degree of weathering increases, and the difference between CIW index values of the silicate parent rock and soil or sediment reflects the amount of weathering experienced by the weathered material.

INTRODUCTION

Weathering indices essentially measure the degree of depletion of mobile components relative to immobile components during weathering. Previously proposed weathering indices, such as the Modified Weathering Potential Index (MWPI; Reiche, 1943; Vogel, 1975), the Vogt ratio (V; Vogt, 1927; Roaldset, 1972), and the Weathering Index (WI; Parker, 1970) are complex and involve many variables. Others are relatively simple [e.g. the Chemical Index of Alteration (CIA) of Nesbitt and Young, 1982]. The aim of this paper is to propose a new and simple chemical index of weathering (CIW) involving molecular proportions of aluminium, calcium and sodium.

DISCUSSION

Chemical changes during weathering

During the weathering of granite and basalt, Si, Mg, Ca and Na are leached, Al and Ti remain essentially in the system and accumulate in the residue, whereas iron

* Contribution of the Ottawa–Carleton Centre for Geoscience Studies.

0037-0738/88/$03.50

TABLE 1

Weathering indices (molecular proportions)

(1) $CIW = [Al_2O_3/(Al_2O_3 + CaO + Na_2O)] \times 100$
(2) $CIA = [Al_2O_3/(Al_2O_3 + CaO + Na_2O + K_2O)] \times 100$
(3) $WI = [(2Na_2O/0.35) + (MgO/0.9) + (2K_2O/0.25) + (CaO/0.7)] \times 100$
(4) $MWPI = [(Na_2O + K_2O + CaO + MgO)/(Na_2O + K_2O + CaO + MgO + SiO_2 + Al_2O_3 + Fe_2O_3)] \times 100$
(5) $V = (Al_2O_3 + K_2O)/(MgO + CaO + Na_2O)$

(1) Chemical Index of Weathering, this paper.
(2) Chemical Index of Alteration (Nesbitt and Young, 1982).
(3) Weathering Index (Parker, 1970).
(4) Weathering Potential Index of Reiche (1943), modified by Vogel (1975).
(5) Vogt ratio (Vogt, 1927; Roaldset, 1972).

and potassium have more complicated behaviours. Because ferric iron is much less soluble than ferrous iron, the proportion of iron remaining in the residue is partly a function of the redox conditions of the system. Potassium is generally leached during soil formation, but most Precambrian paleosols are enriched in K, which is possibly a diagenetic feature (Retallack, 1986). After entering solution, K^+ can be used in the formation of K-minerals, adsorbed on other clays through ion exchange (owing to the higher exchange capacity of K^+, the clay particles have a stronger tendency to adsorb and retain K^+ rather than Na^+ and Ca^{2+}; Kronberg et al., 1987) or removed by fluid migration.

The CIA, WI and MWPI (Table 1) use K_2O as a mobile component. This limits their application to soils and paleosols in which potassium has been actually leached. In the Vogt ratio, K_2O is treated as an immobile component, which is at variance with the evidence that potassium is commonly leached. Because the MWPI includes Fe^{3+} and not Fe^{2+}, its value is partly a function of the degree of oxidation of the material and cannot be applied to metamorphosed paleosols.

The proposed index

A weathering index should: (1) include only those elements which have consistent geochemical behaviour during weathering; (2) be independent of the degree of oxidation of the weathered material; (3) involve chemical elements commonly reported in soil analyses; and (4) be as simple as possible and easy to use.

Using these criteria, the proposed CIW index is an improved measure of the degree of weathering experienced by a material relative to its source rock:

$$CIW = \left[Al_2O_3/(Al_2O_3 + CaO + Na_2O)\right] \times 100$$

where Al_2O_3, CaO, and Na_2O are in molecular proportions. In the proposed index, Al_2O_3 is used as the immobile component. CaO and Na_2O are the mobile components because they are readily leached during weathering. This index does not

TABLE 2

CIW index values of selected weathering profiles

	Rock type	Fresh rock					Most weathered residue
Precambrian paleosols							
[1]Denison	basalt	76	87	90	95	94	96
[1]Pronto	granite	61	61	69	96	95	94
[2]Dominion Reef	granite	59	60	66	93	94	98
Soil profiles							
[3]Tishomingo T1	granite	57	58	70	81	91	92
[3]Tishomingo T2	granite	63	64	71	72	88	82
[4]Kiama	latite	48	63	81	87	89	85
[4]Inverell	basalt	44	85	89	94	95	99
[4]Casino	basalt	32	32	48	62	82	92
[4]Guyra	basalt	39	42	74	85	86	81

The reader is referred to the original publications for a detailed description of the profiles.

[1] Gay and Grandstaff (1980)

[2] Holland (1984)

[3] Harris and Adams (1966)

[4] Craig and Loughman (1964).

incorporate potassium because it may be leached or it may accumulate in the residue during weathering.

The CIW index increases with the degree of depletion of the soil or sediment in Na and Ca, relative to Al. The difference between CIW index values for source rock and soil or sediment reflects the amount of chemical weathering experienced by the weathered material.

The CIW index has been applied to Precambrian paleosols and soil profiles developed on basaltic and granitic rocks (Table 2). For both, the index values show a continual increase as the degree of weathering increases (i.e. as the depth from the top of the weathered profile decreases from left to right).

CONCLUSIONS

The proposed CIW index has been successfully applied to a number of modern soils as well as Precambrian paleosols. It can be applied to silicate rocks of felsic to mafic composition, and is superior to other weathering indices in that it involves a restricted number of components which have simple, well-known and consistent geochemical behaviour during weathering.

ACKNOWLEDGEMENTS

D.F. Sangster, J.M. Richardson and R.E. Ernst read earlier drafts of the manuscript and contributed many valuable suggestions for its improvement.

REFERENCES

Craig, D.C. and Loughman, F.C., 1964. Chemical and mineralogical transformations accompanying the weathering of basic volcanic rocks from New South Wales. Aust. J. Soil Res., 2: 218–234.

Gay, A.L. and Grandstaff, D.E., 1980. Chemistry and mineralogy of Precambrian paleosols at Elliot Lake, Ontario, Canada. Precamb. Res., 12: 349–373.

Harris, R.C. and Adams, J.A.S., 1966. Geochemical and mineralogical studies on the weathering of granitic rocks. Am. J. Sci., 264: 146–173.

Holland, H.D., 1984. The Chemical Evolution of the Atmosphere and Oceans. Princeton Univ. Press, Princeton, N.J., 582 pp.

Kronberg, K.I., Nesbitt, H.W. and Fyfe, W.S., 1987. Mobilities of alkalies, alkaline earths and halogens during weathering. Chem. Geol., 60: 41–49.

Nesbitt, H.W. and Young, G.M., 1982. Early Proterozoic climates and plate motions inferred from major element chemistry of lutites. Nature, 299: 715–717.

Parker, A., 1970. An index of weathering for silicate rocks. Geol. Mag., 107: 501–504.

Reiche, P., 1943. Graphic representation of chemical weathering. J. Sediment. Petrol., 13: 58–68.

Retallack, G.J., 1986. The fossil record of soils. In: V.P. Wright (Editor), Paleosols, their Recognition and Interpretation. Blackwell, London, pp. 1–57.

Roaldset, E., 1972. Mineralogy and geochemistry of Quaternary clays in the Numedal area, southern Norway. Norsk Geol. Tidsskr., 52: 335–369.

Vogel, D.E., 1975. Precambrian weathering in acid metavolcanic rocks from the Superior Province, Villebon Township, southcentral Quebec. Can. J. Earth Sci., 12: 2080–2085.

Vogt, T., 1927. Sulitjelmafeltets geologi og petrografi. Nor. Geol. Unders., 121: 1–560.