ALKALI-REACTIVITY OF SOME JAPANESE CARBONATE ROCKS BASED ON STANDARD TESTS

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ABSTRACT

A series of standard alkali-reactivity tests were made of impure carbonate rocks from Japan. It was suggested that Japanese carbonate rocks that contain more than 10 % of cryptocrystalline quartz and/or acid-insoluble residue can be deleteriously reactive, according to the CSA revised concrete prism test and the CSA accelerated mortar bar test. Some non-dolomitic and dolomitic limestone showed an early deleterious expansion in the concrete prism test, comparable to an alkali-carbonate reactive Canadian aggregate, but were found related to the cryptocrystalline quartz contained in the siliceous and argillaceous matrix or chert nodules in these rocks. This paper discusses the findings and problems of several standard tests applied to Japanese rocks.
Keywords: Accelerated mortar bar test, carbonate rocks, concrete prism test

INTRODUCTION

In Japan, commercially quarried carbonate rocks are generally massive and pure, containing more than 53% of CaO, and are lithologically different from alkali-reactive, impure bedded carbonate rocks in North America. This study focuses on the potential reactivity of some exceptionally impure carbonate rocks in Japan, to examine the potential for alkali-reactivity.

Several Japanese Paleozoic carbonate rocks, not commercially quarried, and two reference Canadian carbonate aggregates (*Table 1*) were selected for standard aggregate testing for alkali-reactivity, such as the CSA concrete prism and accelerated mortar bar tests, the JIS mortar bar test, the ASTM chemical and rock cylinder tests, and petrographic examinations to check the presence of reactive phases. This paper describes the results of these tests.

Table 1 Compositions of some Japanese Paleozoic carbonate rocks

no.	Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	Ig. loss	Insol.
1	Limestone	4.16	0.04	0.32	0.25	0.76	51.68	0.01	0.05	0.03	42.45	4.51
2	Limestone	3.03	0.09	0.49	0.80	1.48	50.77	0.01	0.12	0.04	42.67	5.11
3	Limestone	5.97	0.09	0.46	0.67	1.06	49.42	0.05	0.14	0.01	41.13	7.64
4	Limestone	8.10	0.10	1.74	1.15	2.34	47.86	0.14	0.14	0.00	38.06	9.33
5	Limestone	7.99	0.14	0.80	1.08	1.03	48.16	0.14	0.17	0.08	38.96	11.11
6	Limestone	12.21	0.02	0.78	0.34	1.68	44.69	0.12	0.24	0.14	38.35	12.42
7	Limestone	10.72	0.06	0.35	0.50	2.00	46.20	0.02	0.10	0.07	39.60	12.33
8	Argil. ls	26.53	0.34	2.93	2.13	1.67	35.46	0.31	0.50	0.10	29.27	28.33
9	Ls (chert, meta)	28.39	0.05	1.15	0.44	0.88	37.48	0.16	0.20	0.03	30.95	30.15
10	Ls (chert)	39.57	0.02	0.20	0.13	0.45	32.74	0.03	0.05	0.04	26.23	40.17
11	Ls (chert)	50.57	0.01	0.14	0.29	1.07	25.16	0.01	0.02	0.01	22.44	52.12
12	Dol. limestone	2.25	0.05	0.34	0.84	7.40	45.27	0.01	0.05	0.05	43.34	3.48
13	Dol. limestone	6.36	0.31	1.59	1.70	10.29	38.10	0.10	0.34	0.08	40.03	8.92
14	Dol. limestone	8.74	0.09	2.20	0.78	5.53	42.36	0.08	0.54	0.01	39.46	9.66
15	Dol. ls (chert)	30.98	0.05	0.23	0.73	10.88	24.67	0.05	0.10	3.81	28.17	38.26
16	Dolostone	0.38	0.00	0.02	0.05	18.31	34.20	0.05	0.04	0.07	46.54	0.49
17	Dolostone	0.55	0.00	0.13	0.04	18.87	33.80	0.02	0.02	0.03	46.16	2.12
18	Dolostone	1.23	0.02	0.18	0.19	18.42	34.88	0.01	0.02	0.10	44.84	2.86

Canadian reference: no. 6 Spratt (near Ottawa), no. 14 Pittsburg (Kingston)

PETROGRAPHY OF CARBONATE ROCKS

Paleozoic carbonate rocks from Japan and Canada contain similar impurities, consisting mainly of illite, chlorite, authigenic cryptocrystalline quartz and detrital quartz (***Table 2***). They are also common to matrix constituents of argillaceous and arenaceous rocks which cause an alkali-silica reaction due to crypto- to microcrystalline quartz (e.g. Lewczuk et al. 1990), fomerly called the alkali-silicate reaction. Thus the potential reactivity of carbonate rocks should also be examined in light of the alkali-silica reaction of this mineral.

Limestone

Exceptionally impure portions from Paleozoic limestone beds, containing chert nodules, argillaceous laminations or stylolite seams, were selected for examination. Crypto- to microcrystalline quartz occurs either in the matrix of a bedded limestone (no. 7) similar to the Spratt aggregate (no. 6), or as chert nodules in association with chalcedony, sometimes replacing fossil fragments (no. 11, 12). The size of the cryptocrystalline quartz is generally finer than that of common Paleozoic bedded cherts, suggesting a higher reactivity. By contrast, a weakly metamorphosed limestone, interbedded with chert layers (no. 9) of coarsely-grained quartz, suggests lower reactivity.

Dolomitic limestone

Japanese Paleozoic dolomitic limestones are generally massive and coarsely crystalline, containing dolomite rhombs of 100-200 microns across (no. 12, 13) along with recrystallized calcite of crinoid fragments. They are coarser in texture than Pittsuburg aggregate (no. 14). Chalcedony and cryptocrystalline quartz occur as chert nodules and a siliceous matrix in a dolomitic limestone (***Fig. 1***, no. 15), which suggests a potential for alkali-silica reactivity.

Some impure dolomitic rocks form a "floating texture" of dolomite rhombs surrounded by argillaceous to siliceous matrices. This is because impurities in rocks present abundant nuclei for crystallization of dolomite. A laminated argillaceous dolomitic limestone from Japan has such a floating texture, composed of zoned dolomite of 40-100 microns across (***Fig. 2***, no. 13), similar to the typical texture of Pittsburg aggregate. One might therefore expect that this rock would show alkali-carbonate reactivity (CSA-A23.1, Appx B3.2, 1994).

The Pittsburg aggregate is a finely laminated rock, rich in argillaceous laminae and stylolite seams (***Fig. 7***) consisting of cryptocrystalline quartz, illite and detrital quartz. The high alkali content of this rock is due to illite, which may favor duration of alkali-aggregate reaction in this rock.

Dolostone

A pure type of Japanese Paleozoic dolostone was examined. The samples had a coarsely grained mosaic texture composed of dolomite crystals of 200-350 microns across. Microscopic observation revealed that cryptocrystalline quartz is the main constituent of the acid insoluble residue in these rocks (no. 17, 18).

Fig. 1 Chert nodule in dolomitic limestone (Japan, no. 15)

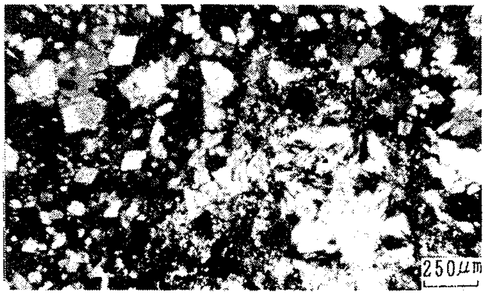
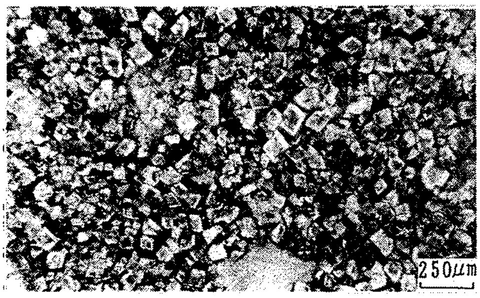


Fig. 2 Floating texture in dol. limestone (Japan, no. 13)



Crystallinity index of quartz

This index (CI) was determined by XRD analysis of HCl-acid insoluble residues. The CI ranged about 4-6 for rocks containing cryptocrystalline quartz (***Table2***), which is lower than that of common Paleozoic chert beds in Japan (Katayama & Futagawa 1989) and suggestive of a higher potential reactivity of this quartz in the carbonate rocks. Detrital quartz has a near perfect crystallinity, i.e. CI of nearly 10, and even in small amounts may overwhelm the intensity of poorly crystallized authigenic quartz associated. For instance, Pittsburg aggregate (no.14), dominated by cryptocrystalline quartz, presents a CI nearly 10 due to detrital quartz. Therefore, this method may not be usable for predicting alkali-silica reactivity of heterogeneous rocks (Wigum 1995).

Phosphoric acid treatment of carbonate rocks

This method completely dissolves carbonates, clay minerals and feldspars, and extracts only silica minerals hidden in the argillaceous matrix of carbonate rocks. SEM observation (***Fig.3***) of the extracts confirmed that Pittsburg aggregate is rich in cryptocrystalline quartz of less than 5 microns across, constituting 85% of the silica residue, and that detrital quartz visible in thin section is a minor constituent. Likewise, Japanese non-dolomitic and dolomitic limestones (nos.7,15) contain abundant cryptocrystalline quartz, which suggests the alkali-silica reactivity of these rocks. The cryptocrystalline quartz in the carbonate rocks has long been missed by thin section microscopy.

Fig.3 Cryptocrystalline quartz extracted by phosphoric acid
A) Limestone (Japan,no.7) B) Dol. limestone (Kingston,no.14)

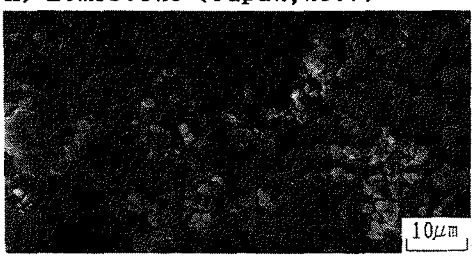


Table 2 Impurities in some Paleozoic carbonate rocks from Japan

		XRD of HCl insol.						SEM of quartz (H_3PO_4 insol.)	
no.	Sample	sm	ch	il	qz	fs	CI of qz	Cryptocryst.	Megacryst.
1	Limestone		+	+	++++		8.5		
2	Limestone	+		+	+++		9.1		
3	Limestone	+		+	+++	+	7.5		
4	Limestone		++	+	++++		9.7		
5	Limestone		+	+	++++		10.7		
6	Limestone		+	+	++++		6.0	3-10 μm 65%	35%*
7	Limestone			+	++++		4.8	1- 3 μm 98%	< 2%
8	Argil.ls		+	+	++++	++	6.1		
9	Ls (chert, meta)			+	++++		9.1		
10	Ls (chert nodule)				++++		5.1		
11	Ls (chert nodule)				++++		6.5		
12	Dol.limestone		+		++++		9.8		
13	Dol.limestone		+	+	++++		9.8		
14	Dol.limestone		+	++	+++	+	9.9	2- 5 μm 85%	15%**
15	Dol.ls (chert nod)				++++		4.4	2- 7 μm 95%	< 5%
16	Dolostone		+	+++	++	++			
17	Dolostone				++++	+	4.1		
18	Dolostone				++++		6.2		

CI: crystallinity index, normalized to 10.0 for a Japanese pegmatite quartz
sm: smectite, ch: chlorite, il: illite, qz: quartz, fs: feldspar
no.6 Spratt, no.14 Pittsburg, * mosaic of chalcedony, ** detrital quartz

STANDARD TESTS OF CARBONARE ROCKS

Concrete prism test

The CSA new version standard test (CSA A23.2-14A, 1994) was conducted up to 6 months, not 1 year as in the standard, due to facility limitations (***Fig.4, Table 3***). Even though, carbonate rocks containing chert nodules were found to be deleteriously late-expansive, exceeding a 1 year limit of expansion of 0.04% even at 6 months. In contrast, rocks rich in cryptocrystalline quartz in the matrix (nos.7,14,15) were early-expansive, reaching the 0.04% limit as early as 1 week, and this is the first example that Japanese non-dolomitic and dolomitic limestones tested as deleterious in the Canadian concrete prism test.

The magnitude of the expansion rate in ***Fig.4*** is similar to that found in the so-called alkali-carbonate reactive dolomitic limestones of the Pittsburg quarry (Grattan-Bellew 1993). However, present test results suggest that a rapid expansion can be caused by the cryptocrystalline quartz with low CI (<5) in the Japanese rocks. This may also be the case with the Pittsburg aggregate (no.14) because it contains large amounts of cryptocrystalline quartz (***Table 2, Fig.3***), and its continued expansion may be due to the high alkali content of this rock due to illite (***Table 1***) which likely supplied alkali to maintain the reaction. An impure alkali-silica reactive limestone aggregate in Ontario has been known to have supplied alkali from illite in the argillaceous matrix to a deteriorated field concrete structure (Grattan-Bellew 1994).

Fig.4 Results of CSA concrete prism test (420kg/m³, 38°C) of some Japanese carbonate rocks

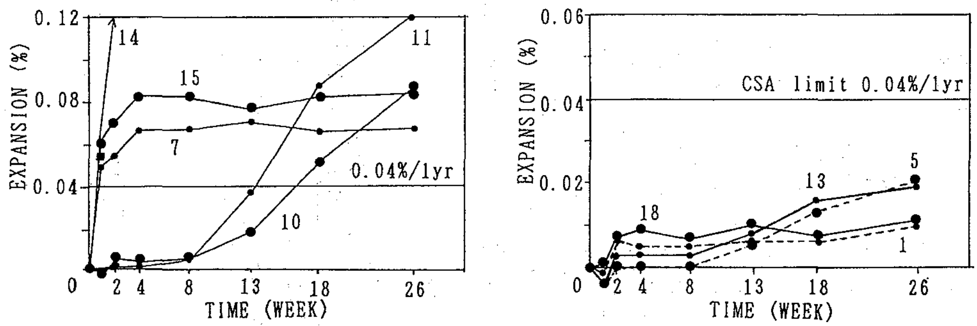


Table 3 CSA concrete prism test (420kg/m³, 38°C) of Japanese carbonate rocks

no.	Sample	1w	2w	4w	8w	13w	18w	26w
1	Limestone	-0.001	0.006	0.005	0.005	0.006	0.006	0.010
2	Limestone	0.005	0.000	0.013	0.017	0.011	0.010	0.012
3	Limestone	0.001	0.000	0.003	0.004	0.005	0.007	0.011
4	Limestone	0.001	0.003	0.002	0.001	0.006	0.004	0.015
5	Limestone	-0.004	0.000	0.000	0.000	0.005	0.013	0.020
7	Limestone	0.049*	0.053*	0.067*	0.067*	0.070*	0.066*	0.067*
8	Argil.ls	-0.007	0.002	0.002	0.000	0.004	0.003	0.007
9	Ls (chert,meta)	-0.002	0.001	0.000	0.000	0.005	0.005	0.018
10	Ls (chert nod)	-0.001	0.005	0.004	0.006	0.019	0.052*	0.086*
11	Ls (chert nod)	0.000	0.002	0.002	0.005	0.038	0.087*	0.120*
12	Dol.limestone	-0.001	0.005	0.004	0.003	0.005	0.007	0.009
13	Dol.limestone	-0.004	0.003	0.003	0.003	0.008	0.016	0.019
14	Dol.limestone	0.055*	0.122*	0.187*	0.220*	0.261*	0.278*	0.297*
15	Dol.ls (chert)	0.061*	0.069*	0.083*	0.082*	0.078*	0.082*	0.083*
16	Dolostone	0.002	0.000	0.008	0.004	0.004	0.002	0.003
17	Dolostone	0.002	0.008	0.010	0.009	0.011	0.008	0.012
18	Dolostone	0.001	0.007	0.009	0.007	0.010	0.007	0.011

* Expansion > 0.04%, Canadian reference: no.14 Pittsburg

Accelerated mortar bar test

This North American new standard test (CSA A23.2-25A 1994) was made on some Japanese carbonate rocks, to compare with the JIS A 5308 mortar bar test done in parallel. Both ***Fig.5*** and ***Table 4*** show that all of the impure carbonate rocks from Japan and Canada, that contain more than 10% of insoluble residue and/or chert nodules (crypto to microcrystalline quartz), produced deleterious expansion in this test, exceeding the 0.15% CSA limit before 14 days. In contrast, the conventional JIS mortar bar test detected deleterious expansion from only one limestone that contained 50% of chert nodules (see ***Table 1***).

The accelerated mortar bar test has been used successfully in Quebec, Canada to evaluate impure carbonate aggregates, but a more critical 0.10% expansion limit after 14 days has been suggested based on concrete prism tests and the field performance of concrete (Fournier & Berube 1991). In Japan, no field record is available of impure carbonate rocks as to judge which test is suitable for evaluating these rocks, because they are not commercially quarried for concrete aggergates in Japan. The CSA concrete prism test, although with limited data up to 6 months (***Table 3***), seems to give a moderate result between the accelerated and conventional mortar bar tests. It will therefore be necessary to examine the expansion limit in the accelerated mortar bar test, when applying this method to various Japanese carbonate rocks.

Fig.5 Results of CSA accelerated mortar bar test of some Japanese carbonate rocks

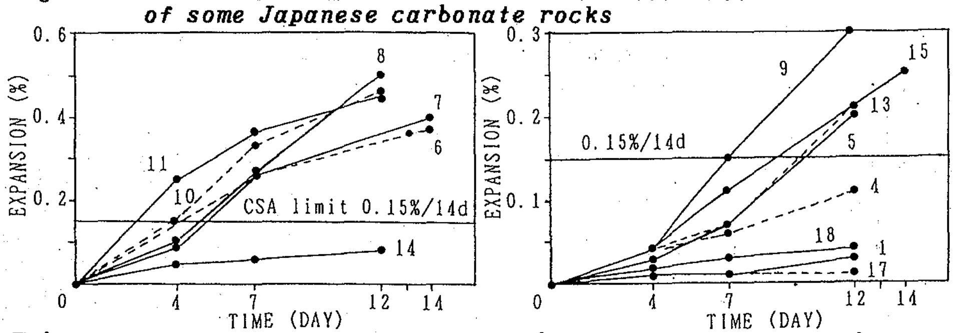


Table 4 CSA accelerated mortar bar test & JIS mortar bar test of some Japanese carbonate rocks

no.	Sample	Accelerated mortar bar test 4d	7d	12d	13d	14d	JIS mortar bar test 2w	4w	8w	13w	26w
1	Limestone	0.01	0.01	0.03			0.005	0.006	0.012	0.010	0.012
2	Limestone						0.000	0.001	0.007	0.009	0.010
3	Limestone						0.000	0.001	0.006	0.009	0.012
4	Limestone	0.04	0.06	0.11			0.006	0.007	0.018	0.016	0.021
5	Limestone	0.03	0.07	0.20*			0.006	0.008	0.020	0.018	0.025
6	Limestone		0.26*		0.36*	0.37*					
7	Limestone	0.09	0.26*			0.40*	0.001	0.005	0.014	0.019	0.021
8	Argil.ls	0.10	0.27*	0.50*			0.002	0.002	0.012	0.013	0.015
9	Ls(chert,meta)	0.04	0.15*	0.30*			0.006	0.008	0.019	0.022	0.027
10	Ls (chert nod)	0.15*	0.33*	0.46*			0.007	0.011	0.033	0.042	0.049
11	Ls (chert nod)	0.25*	0.36*	0.45*			0.013	0.024	0.085	0.124+	0.134+
12	Dol.limestone	0.02	0.01	0.02			0.005	0.005	0.015	0.010	0.015
13	Dol.limestone	0.04	0.07	0.21*			0.007	0.005	0.018	0.017	0.023
14	Dol.limestone	0.05	0.06	0.08			0.029	0.037	0.052	0.056	0.070
15	Dol.ls (chert)	0.04	0.11			0.25*	0.000	0.005	0.014	0.018	0.019
16	Dolostone						0.000	0.004	0.011	0.014	0.015
17	Dolostone	0.01	0.01	0.01			0.005	0.009	0.012	0.010	0.014
18	Dolostone	0.02	0.03	0.04			0.008	0.009	0.015	0.014	0.019

* Expansion > 0.15%, + Expansion > 0.10%
Canadian references: 6 Spratt (CSA interlaboratory test, 1994), 14 Pittsburg

Rock cylinder test

Carbonate rocks without chert inclusions were tested according to ASTM C 586. Since these rocks are heterogeneous, having bedding planes and laminations, cylinders were taken in three directions from each sample, i.e. two crossing directions (x, y) parallel to, and one (z) perpendicular to the bedding plane.

Japanese carbonate rocks comprise the 1) steadily shrinking type, and the 2) late-expansive type which expanded after a long period of contraction (no. 13) (***Table5***). A reference Pittsburg aggregate (no. 14), representing the 3) most deleterious early-expansive type, expanded more than 0.1% by 28 day. All these types are known in the North American Paleozoic carbonate rocks (Lemish & Moore 1964), but their petrography is different in Japan.

The late-expansive dolomitic limestone (no. 13) is a laminated rock with a "floating texture" of coarse-grained dolomite rhombs (***Fig.2***), resembling the typical alkali-carbonate reactive dolomitic limestone (CSA-A23.1). This rock was deleterious in the accelerated mortar bar test, and a rock cylinder perpendicular to the lamination (z) produced expansion after 4 months (***Fig.6***).

The Pittsburg aggregate examined (no. 14) is a finely-laminated dolomitic limestone, with numerous parallel laminations of argillaceous materials, sometimes stylolitic, composed mainly of cryptocrystalline quartz and illite (***Table 2, Fig.7***). This highly expansive rock does not present a typical floating texture, because dolomite crystals are sparse, less than 30% in the carbonate fraction. Thus, the well-known relationship between the petrography and expansivity of carbonate rocks should be reinvestigated without prejudice.

Fig.6 Rock cylinder test of Japanese carbonate rocks

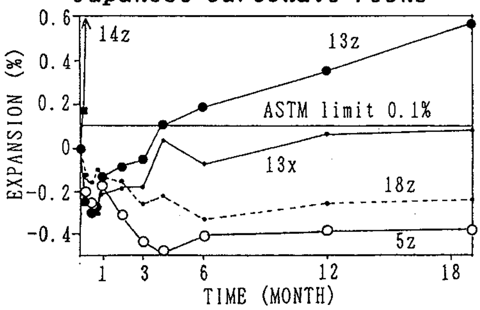


Fig.7 Laminated texture of dol. limestone (Kingston, no.14)

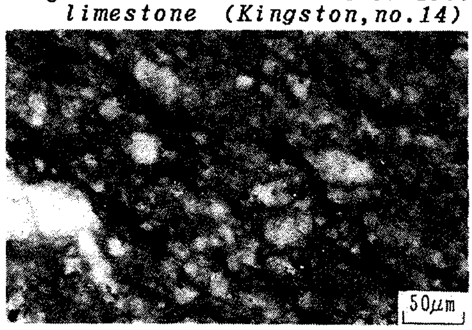


Table5 Rock cylinder test of Japanese non-cherty carbonate rocks

no. Sample		7d	14d	21d	28d	2m	3m	4m	6m	1y	1y7m
5 Limestone	x	-0.17	-0.24	-0.27	-0.17	-0.30	-0.43	-0.43	-0.43	-0.40	-0.43
bedded	y	-0.19	-0.26	-0.28	-0.19	-0.31	-0.43	-0.46	-0.42	-0.41	-0.45
	z	-0.20	-0.26	-0.26	-0.17	-0.32	-0.43	-0.49	-0.40	-0.38	-0.38
8 Argil. ls	x	-0.15	-0.22	-0.21	-0.22	-0.30	-0.39	-0.40	-0.47	-0.41	-0.43
bedded	y	-0.16	-0.20	-0.22	-0.21	-0.28	-0.37	-0.39	-0.43	-0.36	-0.38
	z	-0.12	-0.18	-0.19	-0.21	-0.29	-0.36	-0.34	-0.43	-0.35	-0.33
12 Dol. ls	x	-0.20	-0.23	-0.24	-0.18	-0.28	-0.37	-0.33	-0.40	-0.34	-0.38
bedded	y	-0.21	-0.27	-0.28	-0.23	-0.31	-0.40	-0.43	-0.45	-0.41	-0.43
	z	-0.24	-0.28	-0.23	-0.25	-0.34	-0.40	-0.45	-0.46	-0.45	-0.46
13 Dol. ls	x	-0.23	-0.29	-0.29	-0.21	-0.18	-0.18	0.03	-0.07	0.06	0.08
laminated	y	-0.25	-0.29	-0.28	-0.16	-0.21	-0.21	-0.12	-0.09	0.01	0.06
	z	-0.24	-0.30	-0.27	-0.13	-0.08	-0.06	0.10	0.18	0.34	0.57
14 Dol. ls	x	0.44	1.23	2.11	2.72	5.64	7.15	8.11	8.49	8.84	9.51
finely lam-	y	0.36	1.09	2.03	2.67	5.50	7.12	8.25	8.90	9.21	9.45
inated	z	0.18	1.18	2.52	3.31	7.78	10.45	12.25	13.40	14.14	13.60
18 Dolostone	x	-0.12	-0.17	-0.16	-0.19	-0.27	-0.36	-0.34	-0.42	-0.37	-0.38
massive	y	-0.14	-0.15	-0.15	-0.15	-0.16	-0.23	-0.27	-0.39	-0.37	-0.34
	z	-0.13	-0.17	-0.10	-0.13	-0.16	-0.26	-0.22	-0.32	-0.25	-0.23

no. 14 Pittsburg aggregate, x, y: parallel, z: perpendicular to bedding plane

Chemical test

Impure carbonate rocks were subjected to the ASTM C289 chemical test (***Table 6***). Dissolved silica (Sc) increased with the increased content of insoluble residue in these rocks, proportionally to the content of chert nodules composed mainly of crypto- to microcrystalline quartz. Weakly metamorphosed limestone, containing bedded chert, has a low Sc, because the included quartz is coarsely grained and thus less reactive.

A modified chemical test was made for selected samples using HCl-insoluble residue, to remove interferences from carbonate minerals on Sc & Rc values. A tentative result is shown in the ASTM diagram (***Fig.8***), with the Sc & Rc values normalized to a residue amount of 12.5g, to compare with Canadian data. Many researchers use only Sc values for consideration, since Rc values are affected by many factors. In Quebec, Canada, values with 1) Sc>100 mmol/l, or 2) corrected Sc*>10 mmol/l (Sc*= Sc x insol.%/100), or 3) insoluble residue > 5%, are considered as indications of deleterious Paleozoic carbonate rocks, based on the correlative data of the CSA concrete prism and the accelerated mortar bar tests (Fournier & Berube 1990). Impure carbonate rocks from Japan have the same magnitude of Sc & Sc* as the Canadian rocks (***Table6***), giving a prospective impression for the items 1) & 2), but further study coupled with other tests is needed to apply this method to Japanese carbonate rocks.

Fig.8 Chemical tests of some impure Japanese carbonate rocks

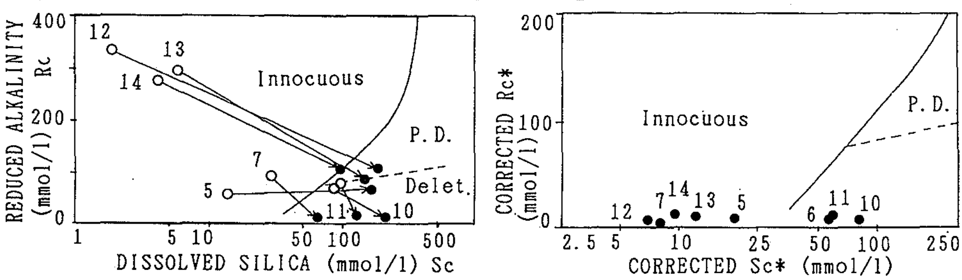


Table 6 Chemical tests of some Japanese carbonate rocks

no.	Sample	ASTM C289 Sc (mmol/l)	Rc (mmol/l)		Modified test for insol. Sc (mmol/l)	Rc (mmol/l)	Sc* (mmol/l)	Rc* (mmol/l)	Expansion tests CP	AM	Insol. (%)
1	Limestone	6	29	I							4.51
2	Limestone	9	54	I							5.11
3	Limestone	9	49	I							7.64
4	Limestone	19	55	I							9.33
5	Limestone	12	57	I	177	67	20	7		#	11.11
6	Limestone				449	66	56	8		#	12.42
7	Limestone	27	97	I	67	9	8	1	#	#	12.33
8	Argil.ls	37	98	I						#	28.33
9	Ls (chert, meta)	11	39	I						#	30.15
10	Ls (chert nodule)	84	68	D	194	18	78	7	#	#	40.17
11	Ls (chert nodule)	97	88	D	118	19	61	10	#	#	52.12
12	Dol.limestone	2	334	I	195	108	7	4			3.48
13	Dol.limestone	6	299	I	147	94	13	8		#	8.92
14	Dol.limestone	4	282	I	93	115	9	11	#		9.66
15	Dol.ls (chert nod)	65	320	I					#	#	38.26
16	Dolostone	1	395	I							0.49
17	Dolostone	0	372	I							2.12
18	Dolostone	1	384	I							2.86
19	Chert nodule	148	125	PD							

no.6 Spratt, no.14 Pittsburg, no.19 isolated from limestone no.10
* Corrected value, multiplied by insoluble residue content
I: innocuous, PD: potentially deleterious, D: deleterious
CP: concrete prism test, AM: accelerated mortar bar test, #: deleterious

CONCLUSIONS

- The SEM observations of the extracted residue from phosphoric acid treatment revealed that some impure dolomitic (Pittsburg) and non-dolomitic limestone (Spratt) from both Canada and Japan, contained abundant cryptocrystalline quartz, which suggested their higher potential for alkali-silica reactivity.
- The CSA concrete prism test gave moderate expansions among the testing methods examined, which revealed that some of Japanese non-dolomitic and dolomitic limestones, containing more than 10% of cryptocrystalline quartz and/or acid insoluble residue, were deleterious.
- The CSA accelerated mortar bar test was very sensitive and overestimated the potential reactivity of Japanese carbonate rocks, while the conventional JIS mortar bar test clearly underestimated the reactivity. The expansion limit of this accelerated test needs investigation when applied to Japanese rocks.
- The ASTM rock cylinder test revealed the presence of a late-expansive dolomitic limestone in Japan, also deleterious in the accelerated mortar bar test. The Canadian modified chemical test appeared applicable to siliceous carbonate rocks in Japan, but needs further study coupled with other methods.

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