

ALKALI-SILICA REACTIVITY OF ALLUVIAL DEPOSITS  
EVALUATED USING CHEMICAL AND PSAMMOGRAPHIC METHODS

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Alluvial Olocenic deposits which occur in Eastern Italy south of the river Po are studied from the ASR point of view, by making a comparison between the results of chemical and psammographic analysis. The ASTM-C289 procedure was followed for the chemical analysis; psammographic analysis were based on the identification and counting of the reactive particles using a petrographic microscope. In both cases, carbonates were previously eliminated by means of hot diluted HCl; the comparison between data obtained from the two above cited techniques allowed an evaluation of the ASTM-C289 response.

INTRODUCTION

The alkali-silica reaction, which was almost unknown in Italy until a few years ago, has begun to be studied due to some serious structural damages that occurred, in the eighties, in the south-eastern part of the country. During the studies carried out to investigate the causes of the first detected damages, both chemical and petrographic methods were used. It finally appeared clear that the alkali-silica reaction was responsible for the damages; in various cases, however, chemical methods indicated that the aggregates used to build damaged structures (and confirmed as highly reactive when using psammographic analysis) were non-reactive or low reactive (Baronio (1)).

The authors carried out a compared analysis of such alluvia by means of both chemical and psammographic methods (included in a wider study with the purpose of characterizing the alluvial deposits occurring in the Italian peninsula south of the river Po under the alkali-silica reaction aspect) in order to investigate the reasons for such different results.

During the first phase of this study, natural aggregates obtained from all quarried alluvia recently deposited (Olocenic period) by rivers and streams on the eastern appenninic side (from Piacenza, immediately south of the river Po, to Foggia, south of the Gargano peninsula - see Fig.1) were studied by means of psammographic analysis (Barisone et al (2)); 64 samples were collected and examined in this phase.

During the second phase, chemical determinations were made

on almost 20 samples, from among the most significant examined during the first stage; in these determinations the ASTM-C289 procedure was followed.

#### THE GEO-LITHOLOGICAL CONTEXT

The main reactive mineral in the studied alluvia is flint (by this term one means the complex of semi-amorphous or crypto-cristalline reactive minerals, such as calcedony, jasper, etc.); the presence of opal (or rather opaline silex) and microfossiles (mainly radiolarites) is far less important, and the reactivity due to undulatory extinction quartz (which here rarely presents a high undulatory extinction angle) is uncertain (Barisone (3), Rossetti et al (4), Andersen and Thaulow (5)).

The flint found in alluvia comes from the erosion of chert-rich sedimentary formations, widely outcropping in the Appennine range. These formations cover a wide period of ages, from Triassic to Miocenic; on average, however, chert is more frequent in Mesozoic "complete series" and in some Miocenic stages (Langhian, Aquitanian), and scarcely occurs in sedimentary Oligocenic formations and in Mesozoic "reduced series".

From a lithological point of view, the more important chert-bearing rocks are limestones, sandstones and marls, mainly of Jurassic, Cretaceous and Miocenic age.

#### ALLUVIAL DEPOSITS ANALYSIS

A great problem was posed by the sampling, above all because of the mainly coarse granulometry of quarried alluvial deposits and the non homogeneous concentration of reactive minerals in the different granulometric classes, which theoretically requires the collection of very large weights (up to 100 kg) of material, in order to obtain a good representativity (Gy (6) (7)). This problem was solved by collecting the samples in the stock piles of crushed sand produced in the quarries, therefore limiting the weight of each sample to about 5 kg of "sand", thanks to the homogenization due to the industrial crushing of coarse alluvia (Barisone (8)).

Due to its rapidity and good reliability, the psammographic analysis of the so collected sands took place first. Each sample was sieved, after quartering and the elimination of carbonates in diluted HCl, in order to obtain eight granulometric classes which were tested separately using a petrographic microscope; the percentage of the various reactive minerals in each aggregate was calculated as the ponderate average of the eight determinations. The residue after chemical attack, and the total amount of flint (both in % and referring to the original weight sample) are given in Tab.1.

After this, chemical tests were carried out on almost 20 alluvial deposits among those that psammographic analysis determined as being the most significant from the mineralogical point of view or for the high content of potentially reactive minerals. The tests were carried out following the ASTM-C289

TABLE 1 - Synthesis of psammographic analysis results.

Sample N.	River	Psammographic analysis		
		Insol. HCl [%]	Flint av. [%]	Opaline silex (Microfossil.)
2	Biferno	18.8	8.5	+
3	Biferno	15.6	7.8	+
6	Sangro	15.0	6.7	+
7	Sangro	14.6	4.0	+
10	Pescara	11.1	4.4	-
12	Pescara	13.0	4.9	-
18	Salinetto	16.5	8.8	+
20	Tronto	10.3	5.5	-
21	Tronto	43.0	9.4	-
25	Chienti	21.0	10.7	-
28	Esino	12.3	10.4	+
29	Esino	26.0	17.3	+
38	Lamone	95.2	2.5	+
40	Santerno	68.5	7.3	+
42	Sillaro	34.0	13.5	+
58	Biferno	66.4	7.1	+
59	Fortore	63.5	17.5	+
60	Cervaro	17.3	4.6	++
62	Ofanto	62.3	14.5	+
121	Trigno	12.5	5.4	+
122	Trigno	25.2	5.4	+
123	Treste	10.8	1.4	+
124	Treste	10.0	1.6	+

procedure, in order to be able to compare the results of this standardized chemical analysis and those obtained by psammographic determinations.

It is useful to remember here the outlines of the ASTM-C289 method (ASTM (9)): a sample of 25 g is crushed to 0.30-0.15 mm and treated with a 1N solution of NaOH at 80 C for 24 hours; the reduction in alkalinity and the dissolved silica are analyzed on the filtrate.

In this study, however, a problem was posed by the high carbonate content of the alluvia which were tested, these carbonates being able to considerably alterate the chemical analysis results (Fournier and Berube (10)); each final sample was therefore obtained by: 1) crushing and quartering from the original sample until a weight of 100 g was reached; 2) chemical attack with diluted HCl to fully eliminate carbonates; 3) quartering to obtain the weight of the sample to be tested (weight of aggregate residue corresponding to 25 g of the original sample).

To verify the effects of such a treatment on the reactivity degree obtained by the ASTM-C289 method, tests were also carried

out on some non-treated samples, which showed a marked under-evaluation of potential reactivity.

The data obtained from all these tests are shown in Tab.2.

TABLE 2 - Synthesis of chemical analysis results.

Sample N.	River	Insol.	ASTM C-289		Psamm. anal.
		HCl [%]	Rc [mM/l]	Sc	Flint av. [%]
2	Biferno	24.2	35	170	8.5
3	Biferno	untr	245	30	7.8
3	Biferno	37.2	8	150	7.8
6	Sangro	10.4	80	572	6.7
6	Sangro	10.4	20	201	6.7
7	Sangro	12.6	50	62	4.0
7	Sangro	12.0	70	93	4.0
7	Sangro	14.0	55	83	4.0
10	Pescara	untr	117	22	4.4
10	Pescara	10.5	33	112	4.4
10	Pescara	10.8	8	125	4.4
12	Pescara	17.6	58	154	4.9
12	Pescara	17.6	15	46	4.9
18	Salinetto	untr	127	19	8.8
18	Salinetto	15.6	38	302	8.8
18	Salinetto	15.6	15	214	8.8
20	Tronto	10.4	42	122	5.5
20	Tronto	10.4	25	110	5.5
21	Tronto	43.6	11	600	9.4
21	Tronto	43.6	13	150	9.4
25	Chienti	22.8	70	456	10.7
25	Chienti	22.8	35	260	10.7
28	Esino	11.4	109	164	10.4
28	Esino	11.7	105	118	10.4
29	Esino	untr	132	37	17.3
29	Esino	31.8	18	176	17.3
29	Esino	28.4	45	143	17.3
38	Lamone	untr	130	12	2.5
38	Lamone	untr	27	29	2.5
38	Lamone	94.4	55	110	2.5
40	Santerno	71.6	42	58	7.3
42	Sillaro	40.0	140	146	13.5
58	Biferno	68.4	115	151	7.1
59	Fortore	64.0	115	46	17.5
60	Cervaro	27.6	115	51	4.6
62	Ofanto	untr	150	12	14.5
62	Ofanto	67.6	90	130	14.5
121	Trigno	25.4	85	200	5.4
122	Trigno	23.6	95	160	5.4
123	Treste	10.4	80	95	1.4
124	Treste	9.9	75	110	1.6

### CONCLUSIONS

The study shows some anomalies between the results of psammographic and chemical determinations. In particular, microscope analysis often shows potentially reactive mineral contents theoretically corresponding to very high reactivity levels (flint contents between 2% and 7%); on the other hand, chemical analysis places almost all the aggregates tested in the non-deleterious field, if carried out without the elimination of the carbonatic minerals, and in the deleterious field if carried out with the elimination of these minerals.

It appears difficult to detect the reasons for the possible over-estimation of potential reactivity made by means of psammographic analysis: in the authors opinion, this might be due to the problems posed by a correct identification of altered minerals and to the different reactivity degree of the various theoretically reactive minerals, which is, at this moment, not clear enough.

On the contrary, the under-estimation often found in Italy in determining the potential reactivity of aggregates using the ASTM-C289 method seems usually due to the presence of carbonates, clearly indicated in literature as negatively influencing this chemical method; if carried out after the elimination of all carbonatic minerals by means of diluted HCl, however, this method also appears to give an over-estimation of potential reactivity in the Rc-Sc diagram.

The correspondence between chemically "deleterious, potentially deleterious and innocuous" aggregates and the total average content of potentially reactive minerals obtained by microscope counting is shown in Fig.2, where it is possible to distinguish (for the samples in which carbonates were eliminated) two areas, although partially superposed, respectively grouping the samples with a flint content between 6% and 12% and those with a flint content greater or smaller.

As a final comment, both the above cited areas are distinguished by the same range of Rc values, whilst the samples with a flint content between 6% and 12% have normally higher Sc values, so evidentiating a greater importance of this parameter in a preliminary evaluation of potential reactivity of Italian aggregates.

### ACKNOWLEDGMENTS

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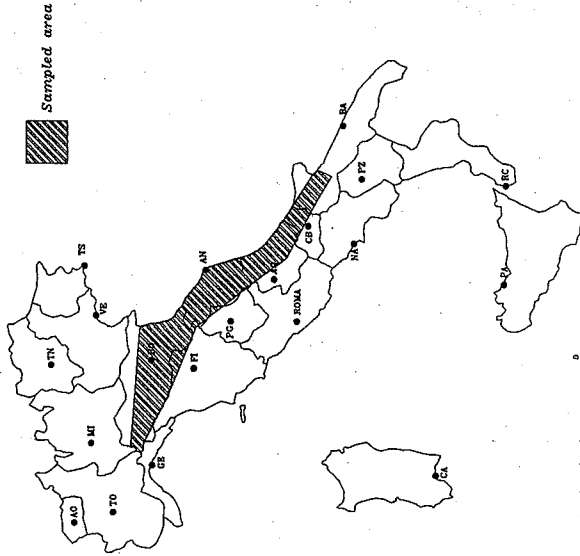


Figure 1 - Schematic map of the sampled area

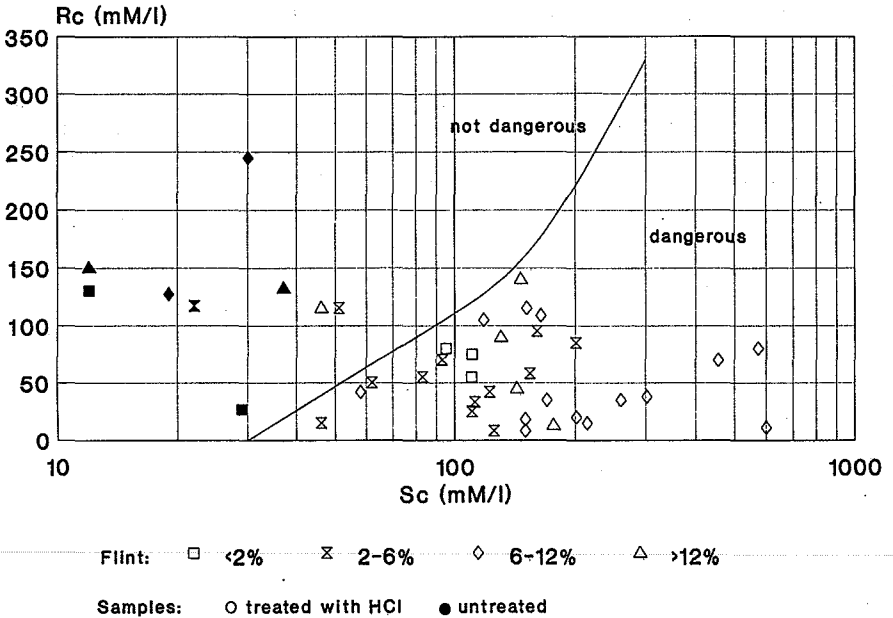


Figure 2 - Distribution of samples with different flint contents in the Rc-Sc diagram