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1965/171

BENTONITE IN THE UPPER PERMIAN BLACK ALLEY SHALE, BOWEN BASIN, QUEENSLAND.

by

J.E.Thompson and P.G.Duff

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CONTENTS

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OCCURRENCE OF THE BENTONITE (by J.E.T.)

INTRODUCTION

In progress reports on regional geological mapping of the south-western part of the Bowen Basin by joint field parties from the Bureau of Mineral Resources and the Geological Survey of Queensland, many references have been made to "soapy" or "greasy" light-coloured beds of montmorillonitic clay in the Upper Permian succession. These clay beds are most prevalent in a marine or paralic claystone unit overlain by a terrestrial sandy unit containing thin beds of fossil wood, coal and oil shale and underlain by a thick sandy unit containing marine fossils.

The stratigraphy of the Permian succession in the region under consideration has been discussed in detail by Mollan, Exon and Kirkegaard (1964) for the *SPRINGSURE 1:250,000 Sheet area, by Mollan, Exon and Forbes (1965) for EDDYSTONE and by Exon and Kirkegaard (1965) for the north-eastern part of TAMBO. All stratigraphic information in this report has been drawn from these sources, and Plate I and Figure I have been adapted from maps accompanying these reports.

Previous brief descriptions of the Upper Permian clays (Mollan et al, 1964, pp. 65, 102 and figs. 36 and 37; Mollan et al, 1965, p. 7 and Exon et al, 1965 p. 7) were strongly suggestive of bentonite but samples had not been submitted for testing.

During a visit to a Bureau of Mineral Resources geological field party, led by A.R. Jensen, investigating the Upper Permian sequence exposed on the eastern flank of the Springsure-Serocold Anticline, one of the authors (J.E.T.) took the opportunity to visit an outcrop of the formation containing the light-coloured "soapy" clay beds. Samples (A & E) collected from this locality, near Early Storms homestead, were subsequently proved (by P.G.D.) to be bentonite of high quality and, after treatment with dilute sodium carbonate solution, to be comparable with Wyoming bentonite as a base for drilling mud.

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* Subsequent reference to 1:250,000 Sheet areas is signified by the use of capitals for the geographic name e.g. EDDYSTONE

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The stratigraphic position, the areal distribution, and outcrop characteristics of the bentonite-bearing claystone are outlined in this report but for further details of stratigraphy the references previously cited should be studied.

STRATIGRAPHIC POSITION OF THE BENTONITE

The bentonite beds occur in a stratigraphic unit which has been called the "Bandanna Series" (S.Q.D., 1952) and the Bandanna Formation (Maxwell, 1954; Hill, 1957). Phillips (in Hill & Denmead 1960, p. 188) stated that the unit was best exposed at the "southern culmination of Reid's Dome". He recognised

1. a lower subdivision containing tuffaceous sandstone and dark shale with minor beds of coal, oil shale and fossil wood and,
2. an upper "carbonaceous and calcareous shale and mudstone with abundant plant fragments".

Subsequent regional mapping and additional subsurface information gained from oil and coal exploration have led to a more natural subdivision recognizing:

1. an upper terrestrial sandstone and shale unit characterized by thin coal beds, minor oil shale and a widespread basal fossil wood bed, and
2. a lower, massive, grey claystone unit, marine at least in part, containing light-coloured bentonite layers and beds of bentonitic claystone.

The upper unit, formerly included in the "Bandanna Formation", is now equated with the Blackwater Group (Mollan et al, 1965), a terrestrial sequence containing important coal measures in the northern part of the Bowen Basin. The lower, dominantly claystone, unit, formerly known as the "lower part of the Bandanna Formation" has now been formally named the Black Alley Shale (Mollan et al, op.cit.).

Conformably beneath the Black Alley Shale is a sequence of dominantly sandy units containing several shelly horizons as positive evidence of marine deposition. Stratigraphically above the Blackwater Group is a thick succession of terrestrial Triassic red beds, which in the type area is initiated by a distinctive marker bed, the Malta Grit. Thus, the Black Alley Shale occupies a stratigraphic position representing a period of transition between older widespread marine deposition and a younger period of terrestrial sedimentation.

THE BLACK ALLEY SHALE

1. Thickness and lithology

In the type section, three miles south-east of Black Alley Peak on the western flank of the Springsure-Serocold Anticline, the Black Alley Shale is 325 feet thick (Mollan et al, 1965); on SPRINGSURE and EDDYSTONE it ranges in thickness between 200 feet and 400 feet. To the west, in the north-eastern sector of TAMBO, where dips are gentle and exposures are poor, the "Bandanna Formation", (representing both the Blackwater Group and the Black Alley Shale) is about 400 feet thick (Exon et al, 1965). Exon (op.cit.) did not subdivide the unit on TAMBO but recorded a basal claystone and stated that the light-coloured montmorillonite clays, characteristic of the unit in the Reid's Dome area, did not appear to be present. However, intensively cracked exposure surfaces, localized chaotic disturbance of bedding planes and solifluction patterns visible on airphotos, suggest that the claystones in the sequence contain bentonite.

Mollan et al (1965) described the Black Alley Shale in the Reid's Dome area thus "... "dark grey to greenish shale and mudstone with thin interbeds of greasy clay. The clay and shale contain primary tuff and glass shards". In small right bank tributaries of Carnarvon Creek, just downstream from Early Storms homestead, where thin bentonite beds are well exposed, several ferruginized bands usually only from 1" to 2" thick were noted. These bands commonly mark the base of bentonitic layers and are thought to represent short breaks in sedimentation and local low emergence caused by slight lowering of water level over the wide shallow depositional area. A white to colourless crystalline efflorescence at the surface of many exposures of the lower part of the Black Alley Shale is probably gypsum which also occurs on exposed surfaces of the underlying Peawaddy Formation.

The claystone beds of the Black Alley Shale have not been specifically examined in thin section but Arman (in prep.) noted crystal-vitric tuffs and volcanic dust, partly altered to montmorillonite, in specimens of cores and cuttings from B.M.R. shallow drill holes Nos. 2, 5 and 12 on SPRINGSURE (for localities see Mollan et al, 1964). He also recognised a minor amount of glauconite in tuffaceous sediments at the base of the terrestrial succession overlying the Black Alley Shale. The presence of microplankton (Evans and Hodgson, 1965) in that part of the sequence now called the Black Alley Shale is consistent with a marine environment for at least part of that unit. The absence of marine macrofossils may be attributable to the high content of fine volcanic dust in the sediments.

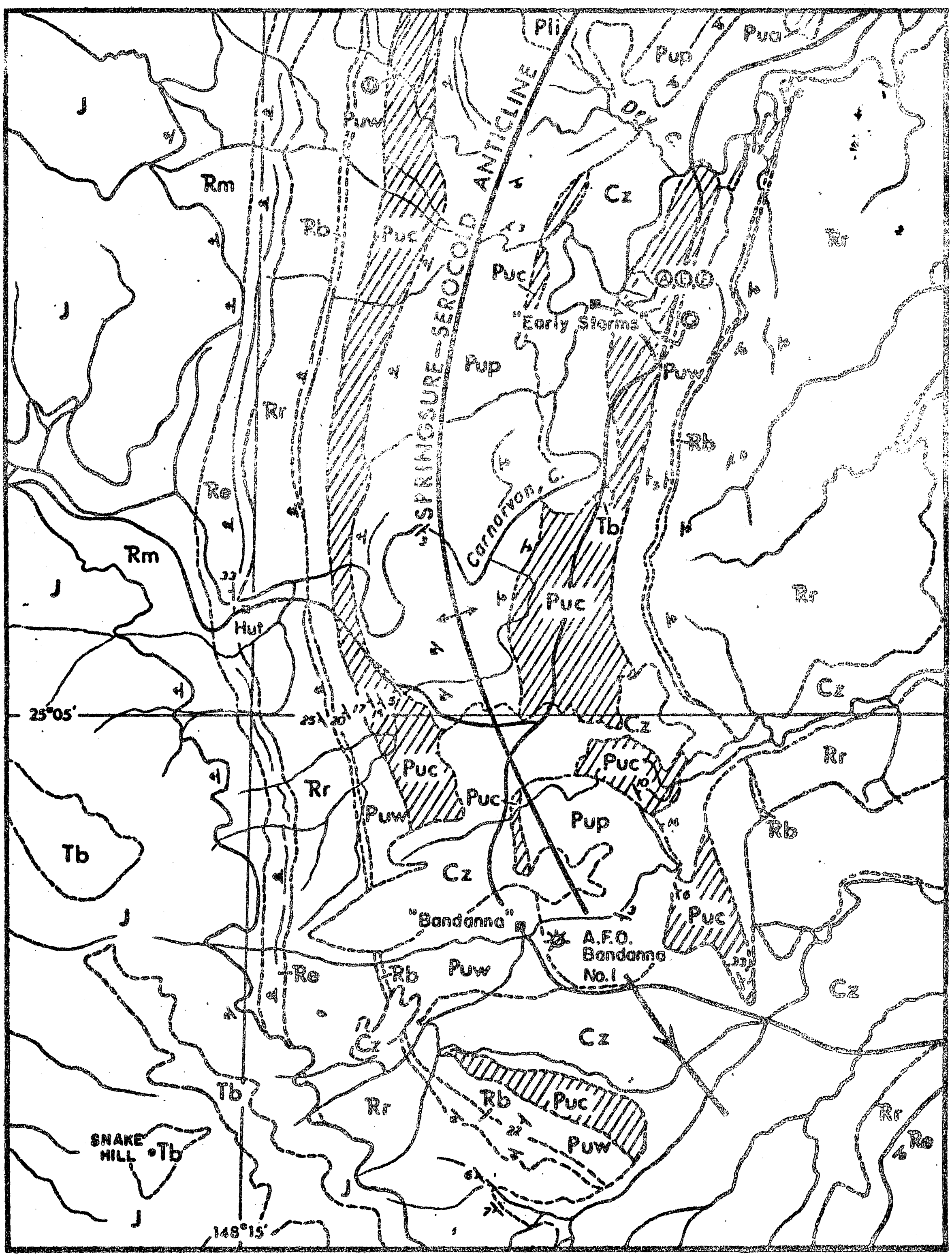
Thin chert beds in the lower part of the overlying terrestrial Blackwater Group and the light-coloured bentonitic layers in the marine, Black Alley Shale may both represent ash bands of similar origin but with different diagenetic histories consequent on their contrasting depositional environments.

2. Areal extent

The Black Alley Shale, being essentially a claystone unit enclosed within sandy units, normally forms low country. Where the dip is moderate, as on the flanks of Reid's Dome and the Consuelo Anticline, the unit is readily traceable on the airphotos as a belt of low-relief topography bounded by strike ridges of the enclosing, more resistant, sandy formations. The low-relief topography developed on the Black Alley Shale is generally undulating to hummocky, reflecting not only the homogeneity of this unit and its susceptibility to erosion, but also the capacity of the bentonitic components to swell during wet times and to contract during dry spells.

THE BLACK ALLEY SHALE ON SOUTHERN NOSE OF SPRINGSURE - SEROCOLD ANTICLINE

Fig I.



SCALE

1 0 1 2 3 4 Miles

Ⓐ *Bentonite sample locality*

		Cz	*Alluvium Thick residual soil, billy boulder gravel*
TERTIARY		Tb	*Basaltic flows*
JURASSIC	*Undifferentiated*	J	*Ferruginous and calcareous sediments*
TRIASSIC	Moolayember Formation	Rm	*Labile sandstone, calcareous in part, siltstone, shale*
	Clematis Sandstone	Re	*Cross-bedded pebbly quartzose sandstone, red silty mudstone*
	Rewan Formation	Rr	*Red and green silty mudstone, green sublabile sandstone*
	Brumby Sandstone Member	Rb	*Pebbly labile and sublabile sandstones*
UPPER PERMIAN	Blackwater Group	Puw	*Green feldspatho-lithic sandstone, siltstone, shale, coal seams*
	Back Creek Group: Black Alley Shale	Puc	*Dark shale, claystone, tuff*
	Back Creek Group: Peawaddy Formation	Pup	*Carbonaceous sandy shale, siltstone, feldspatho-lithic sandstone in top part*
LOWER PERMIAN	Back Creek Group: Ingelara Formation	Pli	*Sandy siltstone with pebbles and granules, shelly calcareous concretions*

There is noticeably less vegetation on the Black Alley Shale terrain than on the surrounding country; it is not known whether this is because of soil deficiencies, swelling of the clays, or because of preferential grazing.

The outcrop distribution of the Black Alley Shale is shown on Plate I which has been compiled from preliminary maps accompanying reports on regional geological mapping of SPRINGSURE, EDDYSTONE and TAMBO by Mollan et al (1964), Mollan et al (1965), and Exon et al (1965) respectively. The unit is well exposed in small streams and gullies but elsewhere is concealed beneath a thin layer of black soil. The outcrop trace in the Springsure area reflects the robust folding. West of the Springsure-Serocold Anticline the outcrop belt extends westerly with a gently sinuous trace reflecting broad folding. In some places the unit is concealed by flood plain alluvium and in other places it is overlain by prominent cappings of Tertiary basalt.

The bentonitic clay samples described in this report were taken at randomly selected localities (Plate I and Fig. 1) on the flanks of the Springsure-Serocold Anticline. The greater part of the outcrop of the Black Alley Shale has not been prospected for bentonite. The two stratigraphic sections through the Black Alley Shale on SPRINGSURE which are graphically portrayed by Mollan et al, (1964) refer to clay bands. One of these sections (Figure 36), measured in a small tributary west of Mount Serocold, on the western flank of Reid's Dome, records a bed, about 8 feet thick, of "soft greenish soapy material". This locality was not visited. The other section (Fig. 37) constructed from observations along and near the Carnarvon Gorge road, west-north-west of the junction with the Bandanna road, refers to "greenish-yellow clay bands up to 2 feet thick". This locality was visited but not sampled; light-coloured clay bands a few inches thick were seen to contain bentonite similar to samples A, E and F from near Early Storms homestead, and above and below these bands the clays were clearly bentonitic.

<u>FEATURES OF BENTONITIC EXPOSURES</u> (Figs. 2 & 3)

The bentonitic clays have distinctive exposures which are dominated by a dense polygonal pattern of open shrinkage cracks. On medium to steep slopes the surface often sloughs down the slope and accumulates in gullies until cleared by floods. The superficial cracking and sloughing are the result of alternate swelling and contraction on wetting and drying. By this process a skin is formed on the outcrop which may mask sedimentary structures. In many places only fragments of good quality bentonite in a mush of bentonitic clay can be seen at the surface and considerable cleaning of the exposure is necessary before the bentonite layer can be precisely located.

Most exposures of the Black Alley Shale in the region of the Springsure-Serocold Anticline have encrustations of white to colourless gypsum or light-yellow jarosite which may be localized on a particular bed or distributed sparsely over the whole exposure. Ferruginized claystone bands up to several inches thick form relatively resistant layers in the otherwise soft claystone sequence. These hard

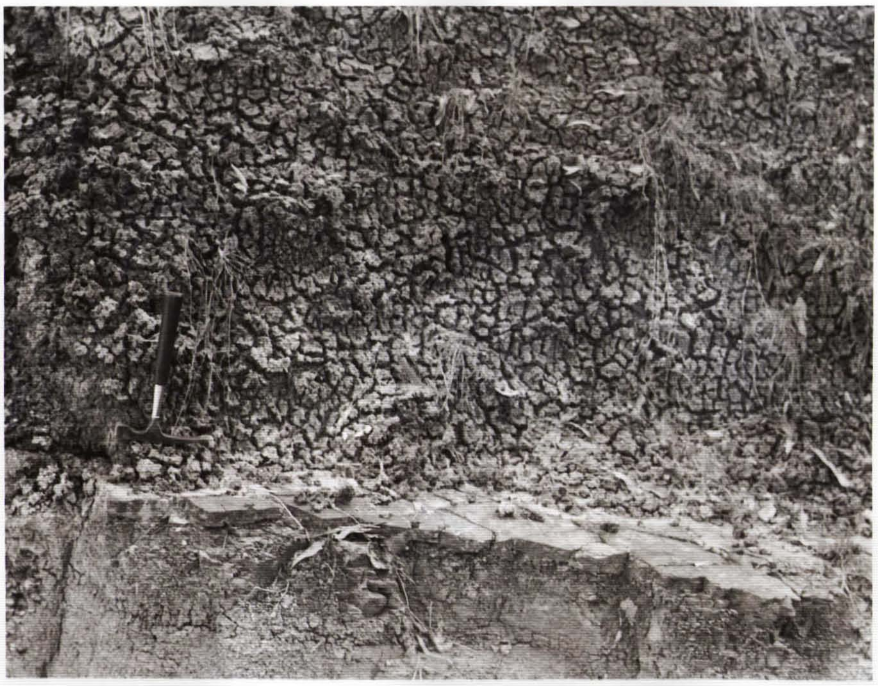


Figure 2 : Polygonal shrinkage cracks in bentonitic claystone. Bench near hammer head formed by 1" thick ferruginized claystone band, ½ mile north-east of Early Storms homestead.

Figure 3 : Swelling bentonite exposure at site of sample E ½ mile north-east of Early Storms homestead.

bands frequently separate bentonitic clays from non-bentonitic clays (see Fig. 2).

Most of the good quality bentonite on surfaces exposed to the sun is white and powdery, whereas, on shaded surfaces or where freshly exposed in damp ground, the bentonite is pale green and "soapy". The pale green, "soapy", bentonite contains about 30% water by weight most of which evaporates on gentle drying to produce the powdery white form.

SAMPLING CONDITIONS AND LOCALITIES

The bentonite samples, lettered A to G, were collected incidentally to other investigations and at the time of sampling it was not appreciated that some of the bentonite had the properties of commercial bentonite used in drilling muds. Further, more accurate, and more detailed sampling will be necessary to locate beds of good quality bentonite in sufficient quantity for economic extraction. Sample localities are indicated on Figure 1 and Plate 1.

Samples A, E, and F were taken from approximately the same locality in the dry gully of a short right-bank tributary of Carnarvon Creek about $\frac{1}{4}$ mile north-east of Early Storms homestead. At this locality the bentonitic claystone sequence is well exposed for about 200 feet along the gully from the junction with Carnarvon Creek. The sequence is similarly well exposed in adjoining gullies. Sample A was collected (by J.E.T.) over a thickness of 18" from the bed illustrated on figure 3. Samples E, over 18", and F, over 6 feet, were collected by A.R. Jensen from the same locality after preliminary testing had indicated good quality bentonite. Sample G was also taken by A.R. Jensen from the lower part of the terrestrial sequence overlying the Black Alley Shale in the head of the same dry gully. Other bentonitic clay bands seen in this area were not sampled; a hummocky outcrop of bentonitic clay exposed by Carnarvon Creek about half a mile farther downstream warrants testing. Following encouragement from preliminary tests on sample E, fragments of high-grade green bentonite which constitute about 70% of the original sample were hand-picked and tested as sample E (1). Three parts of sample E treated with dilute aqueous carbonate solution to effect base exchange are designated "E + Na" on the accompanying graphs.

Samples B and C were collected (by J.E.T.) from two white beds about 15 feet apart in a creek bank exposure of bedded claystone on a tributary of Peawaddy Creek about 100 yards north of the road between Consuelo and Mount Inglis homesteads. The upper bed represented by sample B, is about eighteen inches thick and grades from medium grained tuff near the base to very fine ash upwards. The lower bed, represented by sample C, is from 9 inches to one foot thick and is uniformly fine-grained throughout. The two beds are separated by grey claystone which does not exhibit any swelling features.

Sample D represents bentonitic claystone in the Black Alley Shale exposed in the headwaters of Dry Creek on the western flank of the Serocold-Springsure Anticline; here the exposure is poor and the sample taken over a 1 foot interval may not represent the entire bentonitic section.

LABORATORY TESTING (by P.G.D.)

Seven samples of bentonitic claystone were evaluated in the Petroleum Technology Laboratory for use in drilling muds.

The samples, identified by the letters A to G, have been described and their position and method of sampling are discussed elsewhere in this report.

The testing was carried out in accordance with procedures laid down by the American Petroleum Institute (A.P.I.) using apparatus approved by that authority. A commercial, premium-grade Wyoming bentonite was used for comparison throughout the testing.

EXPLANATION OF TERMS AND TESTS

1. The term "Viscosity" in relation to drilling muds refers to the total or Apparent Viscosity (A.V.) measured on the variable speed, rotational, Fann V.G. Viscometer. The "A.V.", measured in centipoise units, is defined as the force per unit area required to maintain a unit difference in velocity between two parallel layers a unit distance apart. The "A.V." is made up of two distinct components, namely, the Plastic Viscosity (P.V.) and the Bingham Yield (Y.).

2. The "P.V." of a substance is defined as a constant ratio of a given change in the shearing stress to the corresponding change in the rate of shear when the body is undergoing permanent flow. This Plastic Viscosity may be simply described as that part of the "A.V." which is created by the mechanical friction between the solid particles in the mud, between the solids and the liquid that surrounds them and by the shearing of the liquid itself. The measurement of "P.V." is also made in centipoise units.

3. The "Y" value of a plastic substance may be defined as the difference between the shearing stress and the product of the "P.V." and rate of shear. Simply, the "Y" value is that part of the "A.V." which is produced by electro-chemical action between unsatisfied charges on the bentonite and other particles; it is measured in pounds per 100 square feet.

4. The Expressed Filtrate is the volume, in millilitres, of clear liquid which can be forced out of the slurry under test, during a period of 30 minutes, with a pressure of 100 p.s.i.g. through a filter paper 7 square inches in area.

5. The gelling properties of the slurry are determined on the Fann meter where the shear, acting on a slowly rotating cup in the slurry, is measured immediately after agitation for the Initial Gel and, after 10 minutes quiescent standing, to determine the Ten-Minute Gel. These gelling properties are measured in pounds per 100 square feet.

6. A simple test to determine whether a crude sample is bentonitic, is the Benzidine Test. In this test the dried sample is treated with a solution of benzidine hydrochloride in water. If the sample contains a significant amount of bentonitic material it turns deep blue <u>immediately</u>. Samples containing minor amounts of bentonite produce various shades of blue after various time intervals depending roughly on the percentage of bentonite present.

7. The Settling Test is used to determine whether a clay warrants more detailed testing. If after preparing a slurry from the clay, solid particles settle leaving clear liquid on the surface of the slurry then the clay is unsuitable for use in drilling muds.

8. Slurries of various percentages by weight of dry bentonite in distilled water were prepared by high-speed mixing for 30 minutes to give maximum dispersion. The slurry was then allowed to stand for 24 hours to ensure complete hydration of all bentonitic material. Finally, each slurry was given a final 30 minutes high speed mix before testing.

A.P.I. SPECIFICATIONS FOR DRILLING MUDS

The relevant section from "A.P.I. Specification for Oil Well Drilling-Fluid Materials (Tentative). A.P.I., Std. 13A., 1st Edition March 1962"., reads:-

"Section 3. BENTONITE

Bentonite Physical and Chemical Requirements.

Requirement	Numerical Values
Plastic Viscosity	8 cp. minimum
Filtrate	14 ml. maximum
Wet Screen Analysis	
Residue on U.S. Sieve No. 200	2.5% maximum
Moisture	12% maximum

Filtrate and Plastic Viscosity are for a suspension of 21 gm. of bentonite in 350 ml. of distilled water."

SUMMARY OF TEST RESULTS

All slurries prepared from samples B and C settled rapidly and they were not subjected to further testing. Initial testing indicated that samples A and D were clays with a relatively high bentonitic content. Their "A.V." values were not particularly high, but it was found that the "P.V." and the filtrate values were the best that had been obtained for Australian bentonites tested to date by the Petroleum Technology Laboratory.

Test results for samples A, B, C and D are shown on either the accompanying graphs Nos. 1, 2 and 3 or on Table No. 1. Clays tested in the past have given poor results for "P.V." and for filtrate. However slurries prepared from them had pH values between 6.5 and 7.5. The slurries from samples A and D from the Black Alley Shale had pH values between 9 and 9.5 which is comparable with the pH of slurries prepared from commercial grade Wyoming bentonite as supplied in Australia.

Samples E, F and G were tested next. Samples F and G proved to be of poor quality; their 6% slurries having "A.V." values of only 1 cp. and filtrates in excess of 25 ml. The gels of all slurries (up to 9%) of sample G were zero, and only one slurry of sample F was fully tested because it was obvious that results would be similar to those for sample G. Test results for samples E, F and G are shown on either graphs Nos. 1, 2 and 3 or on Table No. 2, 3 and 4.

Sample E proved to be superior to the other clays tested and it is considered to be a bentonite of very high quality. The sample, as received, contained 30% moisture and before drying it was observed that some pieces consisted solely of light green bentonite while other pieces contained white veins and lenses of calcite and (?)gypsum in varying proportions throughout the light green material.

For the first testing, only selected homogeneous, light green material was used. This was called sample E (1). Subsequent testing was carried out using fractions of sample E from which no attempt was made to remove the white veinlets and fine lenses.

The salient feature of the E samples is the relatively high "P.V." value of 4 cp. for the selected material (e (1)) in a 6% slurry and 3 cp. for the material containing white veins and lenses.

BENEFICIATION OF SAMPLE E

Because of the relatively high "P.V." value and the relatively low "Y" value it was thought that simple base exchange treatment of sample E might effect an improvement in mud-making characteristics.

Sodium carbonate was used for the base exchange experiment and three portions of dry sample E were treated as follows:

> The pieces for testing were selected at random and no precautions were taken to exclude the white mineral present as small veins and lenses. They were crushed, and steeped in an aqueous sodium carbonate solution containing 1% sodium carbonate by weight of dry clay. The resulting semi-plastic mass was hand-mixed over a period of several hours and was then dried using a hot air fan. The drying took from 3 to 4 days. After drying each of the treated samples was tested in the same manner as the untreated samples (E and E (1)).

The results from the three treated samples differed considerably because of the heterogeneous composition of the clay (see Table No. 3). The "P.V." values for the treated samples (6% slurries) ranged from 3.5 to 6.5 cp; the sample which had the highest sand content, also had the lowest "P.V.".

In all treated samples the filtrate characteristics were improved; in the best example the filtrate was reduced from 16 ml. in an untreated, 6% slurry to 9 ml. when treated. This value of 9 ml. represents a 5 ml improvement on the A.P.I. specifications and a 2 ml. improvement on the value obtained with Wyoming bentonite at 6% concentration.

QUANTITY YIELD FOR SAMPLE E

Although not included in the A.P.I. specifications, the Quantity Yield value of a bentonite is an important factor to the purchaser of bentonite who will wish to know the volume of mud of a given viscosity that he can obtain from one ton of clay.

Formerly, this calculation was based exclusively on a 15 cp. "A.V." mud, but with the advent of the variable speed, rotational viscometer, some purchasers require to know the volume of 8 cp. "P.V." mud which can be produced from a ton of clay.

Table No. 4 sets out a method of calculating the Quantity Yield and also shows the various quantities of 15 cp. "A.V." mud and 8 cp. "P.V." mud which can be produced from the clays studied.

CONCLUSIONS AND RECOMMENDATIONS

Sample E is a bentonite of good quality suitable for preparing drilling muds, and could replace some of the Wyoming bentonite now being imported from the U.S.A.

Although little has been published on the improvement of bentonitic clays by various treatments, a simple method to further improve these clays could probably be devised.

As the treatment of any clay would have to be carefully controlled to obtain a consistently uniform product it is suggested that, firstly, an endeavour be made to find a naturally occurring bentonite in the Black Alley Shale section which would meet the A.P.I. specification without treatment. Failing this, further experimentation should be done on the bentonite represented by sample E to improve on the results already obtained. For instance, further improvement might be achieved by a small increase of the concentration of sodium carbonate used. Also, alternate wetting and drying with sodium carbonate over a lengthy period of time may prove to be more beneficial than the single steeping used in the tests described here.

The mineralogical and chemical composition of the bentonite and bentonitic clays discussed in this report has not yet been determined but samples will be submitted for X-ray diffraction analysis and silicate analysis.

The specifications for bentonite used for the pelletisation of iron ore are not known to the authors, but it is understood that they vary with physical and chemical composition of particular ores. However, bentonite of the quality represented by sample E would appear to warrant serious consideration and testing for this purpose.

The specifications for bentonite in foundry work are less stringent than use in the drilling muds or for pelletizing and it is likely that bentonite from the Black Alley Shale would be acceptable.

The results of laboratory testing of samples A, E and D have shown that high-grade bentonite is present in the Upper Permian section in the region of the Springsure-Serocold Anticline. Systematic prospecting of the area would involve relatively little effort and expense. The most favourable host unit, the Black Alley Shale, has already been mapped through the region by joint parties of the Bureau of Mineral Resources and Geological Survey of Queensland.

For easy exploitation, deposits of high-grade bentonite would probably have to be at least three feet thick and have less than ten feet of overburden. Reconnaissance prospecting for such deposits could be undertaken by shallow drilling or power augering from a truck-mounted unit. Detailed prospecting of areas not accessible by vehicles could be done by shallow hand-augering or pitting.

The eight foot thick bed of soft-greenish grey "soapy" material recorded (Mollan et al, 1964) in a stratigraphic section measured in a small tributary of Serocold Creek west of Mount Serocold warrants investigation but exploitation in this area would be difficult because of the rugged terrain and the medium dip (20° to 40°) of the beds.

Possibly the best area for prospecting is west of the Springsure Anticline where the dip is flat and the terrain is gently undulating and access by way of existing tracks and roads is good.

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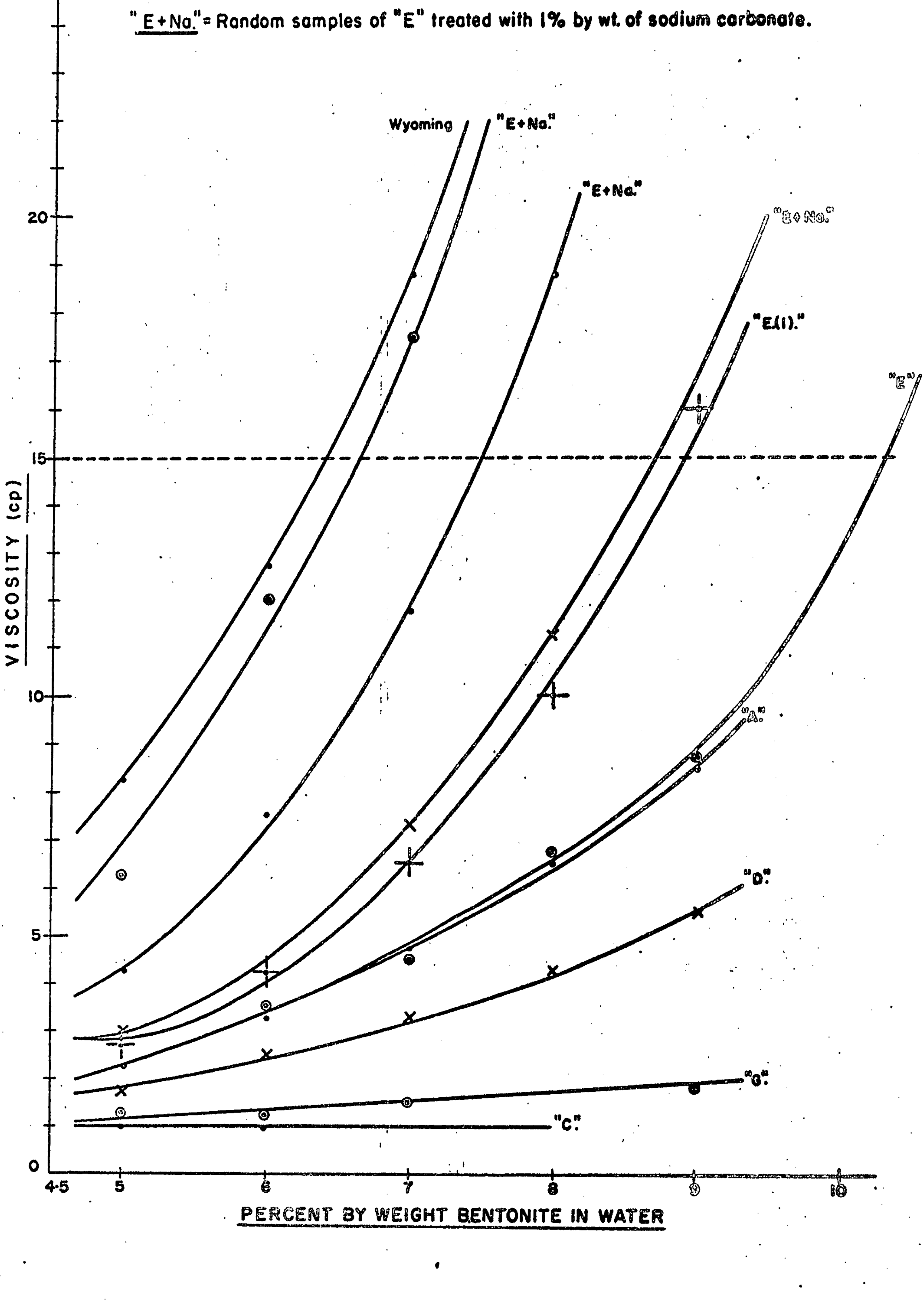
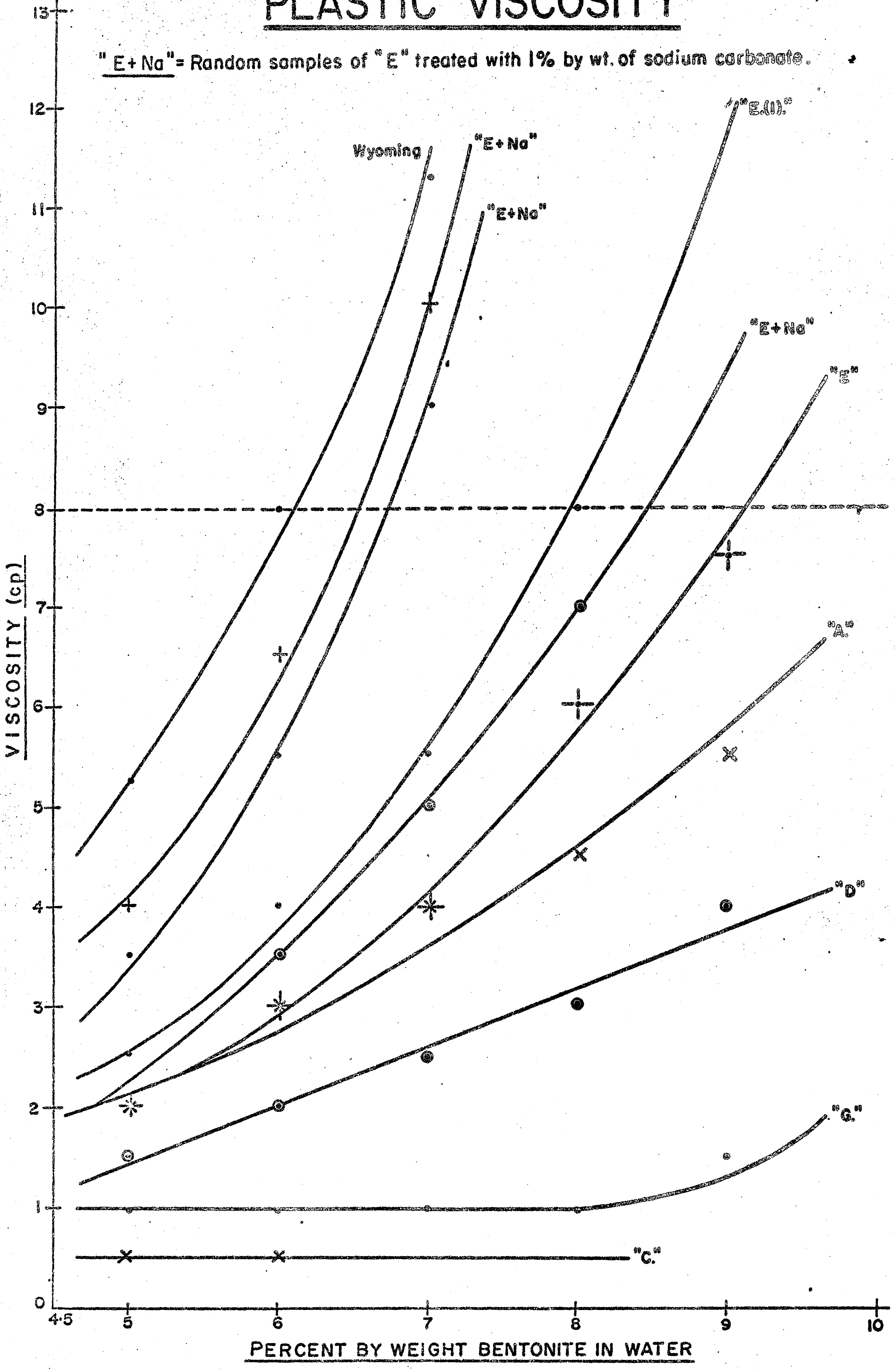
APPARENT VISCOSITY



GRAPH No.2.

PLASTIC VISCOSITY



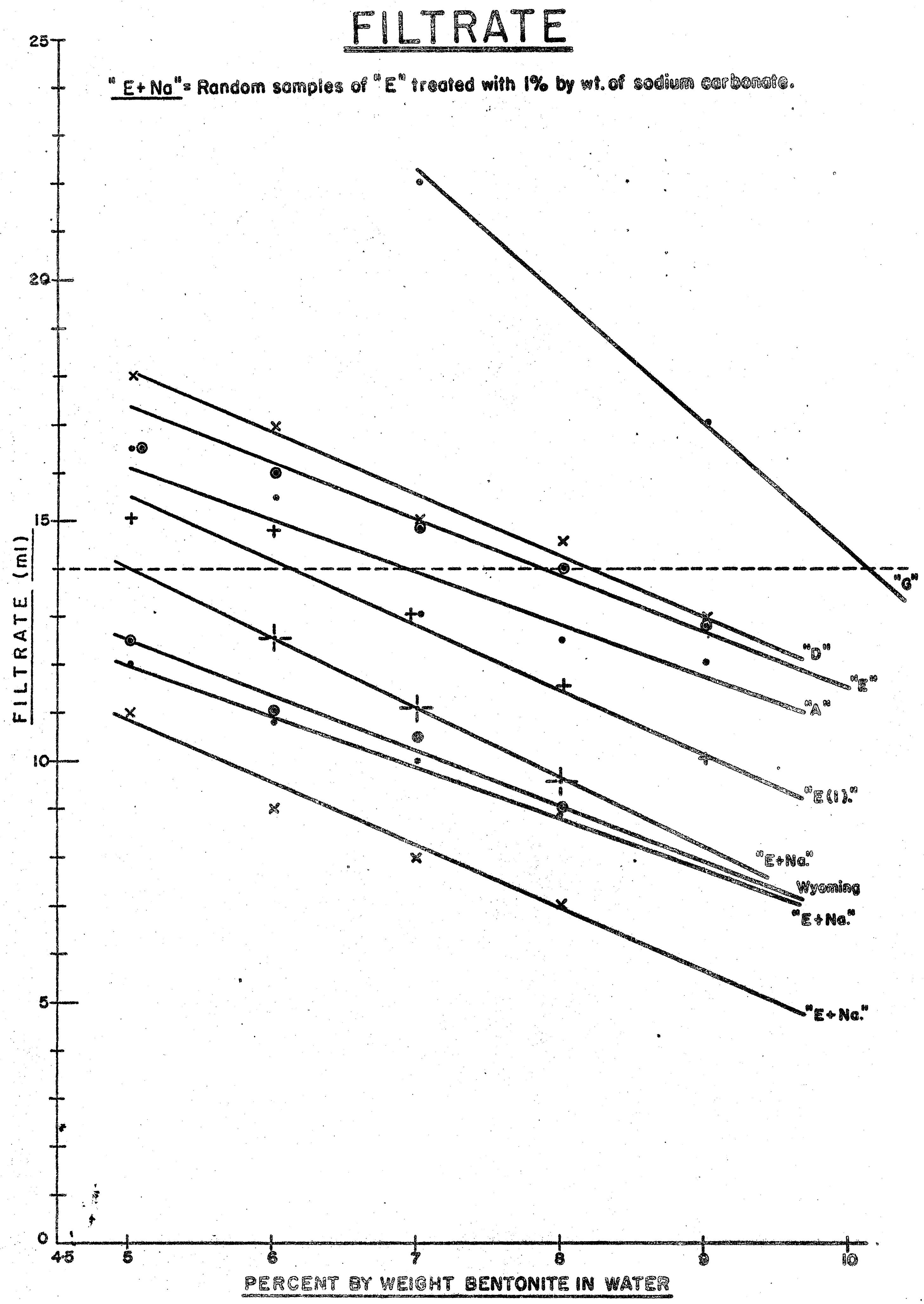

FILTRATE
"E+Na" = Random samples of "E" treated with 1% by wt. of sodium carbonate.
FILTRATE (ml)
25
20
15
10
5
0
4·5
5
6
7
8
9
10
PERCENT BY WEIGHT BENTONITE IN WATER
"G"
"D"
"E"
"A"
"E(I)."
"E+Na."
Wyoming
"E+Na."
"E+Na."

TABLE No. 1.

STANDARD A.P.I. TESTS	SAMPLE "A" % by wt. Bent. in water					SAMPLE "B" % by wt. Bent. in water					SAMPLE "C" % by wt. Bent. in water					SAMPLE "D" % by wt. Bent. in water				
	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9
APPARENT VISCOSITY (Centipoise)	2·3	3·3	4·8	6·5	8·5			ALL			1·0	1·0		ALL		1·8	2·5	3·3	4·3	5·5
PLASTIC VISCOSITY (Centipoise)	2	3	4	4·5	5·5			SAMPLES			0·5	0·5		SAMPLES		1·5	2	2·5	3	4
BINGHAM YIELD (Pounds / 100 sq.ft.)	0·5	0·5	1·5	4	6			SETTLED			1·0	1·0		SETTLED		0·5	1	1·5	2·5	3
INITIAL GEL (Pounds / 100 sq.ft.)	0	0	0	0	1			NO			0	0		NO		0	0	0	0	0
TEN MINUTE GEL (Pounds / 100 sq.ft.)	0	2	5	12	23			FURTHER			0	0		FURTHER		0	0	1	8	10
EXPRESSED FILTRATE (Ml./30 mins at 100 p.s.i.g.)	16·5	15·5	13	12·5	12			TESTING			80	73		TESTING		18	17	15	14·5	13
pH (Hydrion papers)	N.D.	8·5/9	N.D.	N.D.	N.D.			CARRIED			N.D.	8·5/9		CARRIED		N.D.	8·5/9	N.D.	N.D.	N.D.
SAND CONTENT (% by vol.)	N.D.	Trace	N.D.	N.D.	N.D.			OUT			N.D.	N.D.		OUT		N.D.	Trace	N.D.	N.D.	N.D.

OTHER TESTS

BENZIDINE TEST On dry sample	DEEP BLUE					PALE BLUE					PALE BLUE					DEEP BLUE				
SETTLING (Inches in 24 hrs.)	N.D.	Nil	N.D.	N.D.	N.D.	N.D.	8	N.D.	N.D.	N.D.	N.D.	4	N.D.	N.D.	N.D.	N.D.	Nil	N.D	N.D.	N.D.

TABLE No. 2

STANDARD A.P.I. TESTS	SAMPLE "E(1)" Selected light-green clay. No white veins or lenses.					SAMPLE "E" Light-green clay, some with white veins and lenses.					SAMPLE "G" Weathered grey and white clay, some greenish clay.				SAMPLE "F" Appearance of yellow-brown siltstone.
	% by wt. Bent. in water.					% by wt. Bent. in water.					% by wt. Bent. in water.				% by wt. Bent. in water.
	5	6	7	8	9	5	6	7	8	9	5	6	7	9	6
APPARENT VISCOSITY (Centipoise)	2·8	4·3	6·5	10	16	2·3	3·3	4·5	6·8	8·8	1·3	1·3	1·5	1·8	1·3
PLASTIC VISCOSITY (Centipoise)	2·5	4·0	5·5	8·0	12	2·0	3·0	4·0	6·0	7·5	1·0	1·0	1·0	1·5	1·0
BINGHAM YIELD (Pounds / 100 sq.ft.)	0·5	0·5	2·0	4·0	8·0	0·5	0·5	1·0	1·5	2·5	0·5	0·5	1·0	1·0	0·5
INITIAL GEL (Pounds / 100 sq.ft.)	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
TEN MINUTE GEL (Pounds / 100 sq. ft.)	0	0	5	13	26	0	0	3	4	5	0	0	0	0	0
EXPRESSED FILTRATE (Ml. / 30 mins at 100 p.s.i.g.)	15	15	13	11·5	10	15	16	15	14	13	27	25	22	17	24
pH (Hydrion papers)	N.D.	9-9·5	N.D.	N.D.	N.D.	N.D.	9	N.D.	N.D.	N.D.	N.D.	7-8	N.D.	N.D.	7-8
SAND CONTENT (% by volume)	N.D.	Trace	N.D.	N.D.	N.D.	N.D.	0·1	N.D	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Trace

OTHER TESTS

BENZIDINE TEST On wet 'as received' clay.	Trace blue instantly. Strong pale-blue at 30 secs. Strong deep-blue at 2 mins.	As for sample E.(1).	Trace of pale-blue and some dark-blue spots after 3 mins	Material too dark to observe colour.
BENZIDINE TEST On dry clay.	Strong bright-blue immediately.	As for sample E.(1).	As for sample E.(1).	As above.

M(Plt)2

TABLE No. 3

STANDARD A.P.I. TESTS	SAMPLE "E" Light-green clay, some with white veins and lenses. Untreated					SAMPLE "E" Treated with 1% Sod. Carb. by wt. of bent.														
						1st SAMPLE					2nd SAMPLE					3rd SAMPLE				
	% by wt. Bent. in water					% by wt. Bent. in water					% by wt. Bent. in water					% by wt. Bent. in water				
	5	6	7	8	9	5	6	7	8	9	4	5	6	7	8	4	5	6	7	8
APPARENT VISCOSITY (c.p.)	2·3	3·3	4·5	6·8	8·8	6·3	12	17·5	32	TOO VISCOUS FOR TESTS	2·0	3·0	4·3	7·3	11·3	2·5	4·3	7·5	11·8	18·8
PLASTIC VISCOSITY (c.p.)	2·0	3·0	4·0	6·0	7·5	4·0	6·5	10	20	TOO VISCOUS FOR TESTS	1·5	2·0	3·5	5·0	7·0	2·0	3·5	5·5	9·0	14
BINGHAM YIELD (lbs/100ft^2)	0·5	0·5	1·0	1·5	2·5	4·5	11	15	24	TOO VISCOUS FOR TESTS	1·0	2·0	2·5	4·5	8·5	1·0	1·5	4·0	5·5	9·5
INITIAL GEL (lbs/100ft^2)	0	0	0	0	0	0	1	2	5	TOO VISCOUS FOR TESTS	0	0	0	1	1	0	0	1	1	2
TEN MINUTE GEL (lbs/100ft^2)	0	0	3	4	5	16	34	42	58	TOO VISCOUS FOR TESTS	0	12	17	25	35	2	6	18	22	38
EXPRESSED FILTRATE (ml.)	15	16	15	14	13	11	9	8	7	TOO VISCOUS FOR TESTS	16·5	16	12·5	11	9·5	16	12	11	10	9
pH	N.D.	9	N.D.	N.D.	N.D.	N.D.	9·5	N.D.	N.D	TOO VISCOUS FOR TESTS	N.D.	N.D	9·5	N.D.	N.D.	N.D.	N.D	9·5	N.D.	N.D.
SAND CONTENT (% by vol.)	N.D.	0·1	N.D.	N.D.	N.D.	N.D.	Trace	N.D.	N.D.	TOO VISCOUS FOR TESTS	N.D.	N.D.	1·0	N.D.	N.D.	N.D.	N.D.	0·3	N.D.	N.D.

QUANTITY YIELD

DETERMINATION OF QUANTITY YIELD OF SAMPLE 'E (I)'

(a) Quantity Yield of 15cp. 'A.V.' mud. Refer to Graph No. 1.

15 cp. mud is produced at a concentration of 8·9gm. Bentonite in 100ml. water.
This is equivalent to 31·15gm. Bent./ 350ml. water.
This is equivalent to 31·15lb. Bent./ barrel water.
Therefore 2240 lb. of Bentonite will produce 72bbl. of 15cp. mud.

QUANTITY YIELD OF SAMPLE E(I) : 72bbl. of 15cp. A.V. Mud / Ton.

(b) Quantity Yield of 8cp. 'P.V.' mud. Refer to Graph No. 2.

8cp. mud is produced at a concentration of 8·0gm. Bentonite in 100ml. water.
This is equivalent to 28·00gm. Bent / 350ml. water.
This is equivalent to 28·00lb. Bent / barrel water.
Therefore 2240lb. of Bentonite will produce 80bbl. of 8cp. mud.

QUANTITY YIELD OF SAMPLE E(I) : 80bbl. of 8cp. P.V. Mud / Ton.

Sample	Quantity Yield of 15cp 'A.V.' mud from 1 ton of clay.	Quantity Yield of 8cp 'P.V.' mud from 1 ton of clay.
Wyoming	100bbl.	107bbl.
'E + Na'	96bbl.	99bbl.
'E + Na'	85bbl.	96bbl.
'E + Na'	74bbl.	75bbl.
E(I)	72bbl.	80bbl.
E	62bbl.	70bbl.

APPENDIX

Report No. 84.

Total and Exchangeable Sodium in Black Alley Bentonite

by

A.D. Haldane

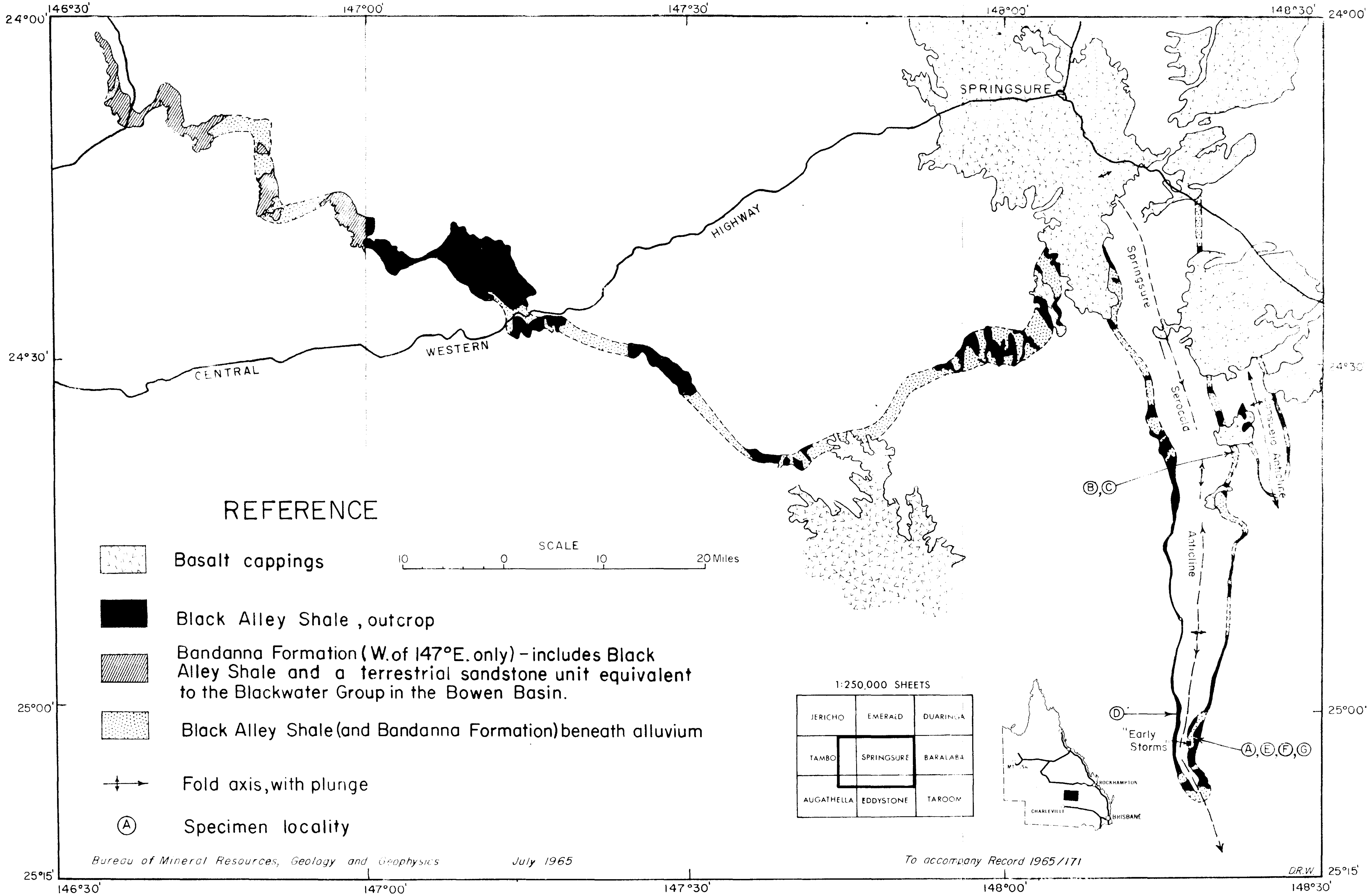
Two samples of "bentonite" from the Black Alley Shale, Bowen Basin, Queensland (see Records 1965/171) were submitted by J.N. Casey for the determination of total and exchangeable sodium. Total sodium was determined by hydrofluoric acid attack of the untreated sample and the exchangeable sodium by leaching with ammonium chloride after removal of soluble salts. The final sodium estimation was by flame photometry in both cases. The results obtained referred to the air dry sample are as follows:

Sample	Total Na	Exchangeable Na	
Black Alley Bentonite, "E"	1.2%	0.9%	39m.e/100 g.
"$E_{(1)}$"	1.2%	1.0%	43m.e/100 g.

DISTRIBUTION OF BLACK ALLEY SHALE

—Other Permian and Mesozoic rock units not shown

PLATE 1



Based on Mapping by R.G. Mollan, N.F. Exon, A.G. Kirkegaard, 1963/4

G55/A/12