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A CLASSIFICATION FOR SEDIMENTARY KAOLINITIC FORMATIONS OF ECONOMIC IMPORTANCE

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ABSTRACT

A wide range of sedimentary geological formations of which kaolin is a major constituent are used industrially for a wide range of uses, ranging from paper to ceramics. All these formations are of fresh water origin and can be looked at as a continuous series ranging from ball clays with high strength and plasticity at one end of the series to sedimentary kaolins with good powder brightness and rheology at the other end. The changes in commercial characteristics from one end of the series to the other can be related to the mineralogy of the sediments.

In a previous communication [BRISTOW, 1977], the writer discussed the classification of primary kaolin deposits formed in-situ, particularly with regard to the problems of differentiating the effects of weathering and hydrothermal processes in their genesis.

This contribution is aimed at trying to produce a workable classification which is rooted in geological principles for sedimentary kaolinitic formations which are commercially exploited.

In the 1977 paper the following classification of kaolin deposits was proposed: —

	(Hydrothermal
	(
Primary	(Weathering
	(
	(Solfatara
	(Kaolinitic Sands
	(
Sedimentary	(Sedimentary Kaolins
	(
	(Ball Clays

Besides the above named there are also flint clays, fireclays and tonsteins, all of which are kaolinitic materials of sedimentary origin which are used commercially.

The writer believes that it is useful to regard these sedimentary kaolinitic materials as forming three continuous series:

Series 1	(Sedimentary Kaolins
	(
	(Ball Clays
Series 2	(Kaolinitic Sands
	(
	(Sedimentary Kaolins

Series 3 (Ball Clays
(
(Fireclays
(
(Flint Clays

Each of these series is continuous and as several types appear in more than one of the series, any clay type may be present in more than one series.

Most clays which have kaolinite as the dominant clay mineral are of fresh water origin, whilst most 'common clays' of marine origin are a mixture of smectite and illite with or without some kaolinite. Of course, only some fresh water clays are of commercial value, the main reasons for not being of commercial value being too high an iron and/or titania content and place value (in an area remote from any area where the clay can be utilised). Other factors such as rheology, particle size distribution and brightness become important for the high value clays such as those used for paper coating and whiteware manufacture and determine whether these clays can be worked in areas remote from centres of consumption.

Series 1

This series comprises most of the non-lithified kaolinitic clays. Nearly all are of Tertiary age.

Five types are quoted in Table 1, taken from well known localities. These could be regarded as 'type localities'.

Type A is the traditional type of coarse particle size sedimentary kaolin as mined in Washington County in Georgia, U. S. A. It is characterised by good brightness, coarse particle size, good rheology and a coarser particle size than the other members of the series.

Type B is the 'North-east' type of sedimentary kaolin, also from Georgia, but generally of a much finer particle size. It is worked as a source of paper coating material.

Type C is an intermediate material between the 'sedimentary kaolins' and the 'ball clays'. It is typified by the refractory clays from the Charente area of the Aquitaine Basin in France.

Type D is the white firing high quality ball clay as typified by the Bovey Basin in Devon, England.

Type E is the highly plastic, very strong ball clay as found in the North Devon (Petrockstow) and Wareham Basins in England.

Below the five types the main characteristics which vary across the series have been listed. The three most fundamental features are the particle size, the crystallinity index and the mineralogy. Chemistry also varies across the series, but not in a regular way and high iron and titania can effectively debar a clay from commercial usage at any point in the series. Organic content does, however, vary in a systematic way, being much higher in ball clays than in sedimentary kaolins largely due to frequent close association with lignites.

The particle size distribution has been commented on by many authors and varies from an *in-situ* below 2 micron content of about 60% for a Type A sedimentary kaolin to about 90% or more for a Type E ball clay. The crystallinity index varies from the relatively well ordered sedimentary kaolins with crystallinity indexes of 0.7 or thereabouts, to thereabouts, to the *b*-axis disordered kaolins which typify most ball clays. The mineralogy also varies in a systematic way with the presence of illite

Table 1

	Sedimentary Kaolins			Ball Clays	
	A	B	C	D	E
	Washington County type coarse particle size sedimentary kaolin	N. E. type fine particle size sedimentary kaolin	Charente refractory clay	S. Devon type white firing ball clays of moderate strength and plasticity	N. Devon type ivory firing ball clays of high strength and plasticity
Patricle size:	Coarse				Fine
Crystallinity index:	Well ordered				b-axis disordered
Presence of illite:	V. little or none				Up to 30%
Organic substances:	Rarely present				Present
Modulus:	Low				High
Plasticity:	Poor				High
Viscosity:	Good for paper coating				Poor
Raw Brightness:	High				Low

rising from close to zero in Type A to around 30% in Type E ball clays. The clay fraction quartz content also increases from Type A to Type E.

Four commercial parameters are also listed in Table 1, two concerned with paper properties and two with ceramic properties. These are doubtless related to the underlying mineralogy, particle size distribution and crystallinity index.

The ceramic property of modulus of rupture varies from very low strength in the case of sedimentary kaolins to high strength in the case of ball clays. Plasticity also varies in a similar way.

The paper property of viscosity concentration varies in relation to the modulus although in the opposite sense with good viscosity clays being found in Types A and B. Raw brightness varies from the good white clays of Type A to the dark grey or brown ball clays of Type E; this is mainly a function of the higher organic content. Fired brightnesses behave independently of the raw brightness, being mainly dependent on the iron and titania content, which varies in a non-systematic way across the series.

Let us now look at a series of 'provinces' where sedimentary kaolinitic formation occur and see how they can be fitted into this concept:

TABLE 2

Sedimentary Kaolins A	Sedimentary Kaolins B	C	Ball Clays E	Ball Clays D
Washington County Type	N. E. Georgia Type	Charente Type	S. Devon Type	N. Devon Type
Georgia, U. S. A.				
			English ball clays	
		Charente, France		
	Amazon, Brazil			
		Westerwald		W. Germany
		Provins		France

Some of the better known occurrences of sedimentary kaolinitic materials are marked on the table with the span of types occurring in each province indicated by a double line for frequent occurrence in the province and a dashed line for infrequent occurrence. By determining the position of the bulk of the clays in a province in the series the approximate commercial characteristics of the materials to be encountered can be inferred.

Series 2

This is a far simple series than the first as the main criterion is the kaolin content, which decreases with increasing sand content. This seems to be a much more polarized series with the bulk of commercially exploited sources lying either in Types A or C. Intermediate types appear to be rare.

TABLE 3

	A	B	C
	Sedimentary Kaolins	Intermediate Types of Sandy Kaolin	Kaolinitic Sands
Kaolin Content:	Over 60 %	______________________	Less than 20 %

The series can run from a type 1D or 1E ball clay through to a kaolinitic sand just as well as with a sedimentary kaolin, although due to the lower value of ball clays in relation to paper clays the refining of kaolinitic sands to produce ball clays is rarely worthwhile.

Examples of kaolinitic sands are the Triassic Hirschau-Schnaittenbach occurrences in West Germany and the Cretaceous occurrences in Cuence and Guadalajara provinces in Spain. Other similar occurrences are found in Poland and Czechoslovakia.

From the literature it would appear that some kaolinitic sands originate as kaolinised arkoses in-situ, whereas others are sediments formed from kaolin and quartz sedimented in that form.

TABLE 4

	A	B	C
	Ball Clays	Fireclays	Flint Clays
Density and Hardness:	Low	______________________	High
Plasticity:	Good	______________________	Non-slaking

Series 3

This is a simpler series, dependent on a single factor — compaction. If a ball clay is buried to a considerable depth and subjected to compaction it will first be converted into a fireclay and then into a flint clay. Whereas a ball clay is soft and plastic and is readily slaked into water, a flint clay is hard, dense and non-plastic [KELLER, 1976]. The microscopic texture of flint clays, as seen under the S. E. M. is indicative of pressure having reduced the porosity so that the crystals of kaolinite are interlocked in such a way that the external crystal form of kaolinite is rarely displayed.

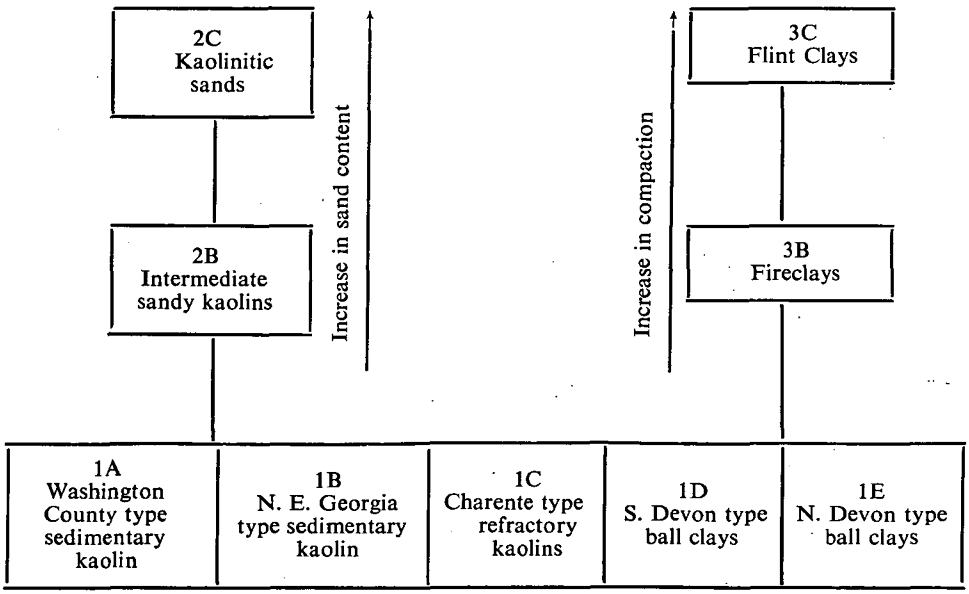
It is not without significance that whereas nearly all ball clays are of Tertiary age, fireclays and flint clays are generally of Palaeozoic age indicating the effects of greater compaction due to deeper burial and/or a greater length of period of burial.

It ought to be mentioned that the term 'fireclay' appears to have a different usage in different countries. The term is of Anglo-Saxon origin and refers to the clays found in association with the Coal Measures of Upper Palaeozoic age in Britain and the eastern United States. Because the type of kaolinite in fireclays is characteristic (*b*-axis disordered), the term 'fireclay kaolinite' began to be used. Subsequently it was found that most ball clays contained the same type of kaolinite. In Germany this had the unfortunate results that any clay which was used for refractory purposes and contained *b*-axis disordered kaolinite came to be called a 'fireclay', at least in commercial circles. This includes a lot of material which most British geologist, would call 'ball clay'. Tonsteins are, of course, a completely different type of clays originating from material of volcanic origin, so cannot be fitted into this classification.

Whilst this series originates from the ball clay end of Series 1; there ought to be an analogous series extending from sedimentary kaolins through to more compacted analogues to fireclays and flint clays. As far as the writer aware no such analogues have been discovered, but it would be very interesting if such a series could be discovered.

The three series are summarised in the following diagram:

TABLE 5



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