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KAOLIN DEPOSITS OF THE CZECH REPUBLIC AND SOME COMPARISONS WITH SOUTH-WEST ENGLAND

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Both the Czech Republic and south-west England (Cornwall and Devon) are globally important producers of kaolin with outputs of 3.0 million tonnes per annum and 0.6 M tpa respectively. The Czech Republic has two main areas of kaolinisation—the Karlovy Vary (kaolinised granites) and Pilsen (sedimentary kaolins) areas—which produce a wide range of products for the paper and ceramic industries. 70% of the Czech production of kaolin is exported. The geology, mineralogy, morphology and commercial utilisation of the Czech kaolins is considered from a number of deposits and compared with kaolins from Devon and Cornwall.

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INTRODUCTION

Out of a world-wide production of 25 M tpa, south-west England (Devon and Cornwall) with 3.0 M tpa and the Czech Republic with 0.6 M tpa are the two largest producers in Europe and the second and fifth largest in the world. 87% of china clay produced in Devon and Cornwall, and 70% of Czech kaolin production is exported. In Devon and Cornwall *ECC International Europe* operates 17 pits and accounts for 90% of the production, with three other companies, *Redlandand Goonvean* and *Rostowrack China Clay* (operating in Cornwall) and *Watts Blake Bearne and Company* (in Devon), producing the rest. The Czech kaolin deposits are mainly situated in the western part of the Republic (Figure 1). There are two major producing companies accounting for 82% of the output. *Zapadoceske Kaolinove a Keramicke Zavody (ZKZ)* operates two mines near Pilsen at Horni Briza and Kaznejov (Figure 2) and produces 345,000 tpa of kaolin from a sedimentary sequence. *Keramicke Suroviny Bozicany (KSB)* has five mines and two processing plants near the town of Karlovy Vary and produces the famous *Zettlitz* ceramic kaolins from altered granites. The objective of this paper is to present general information on some of the Czech kaolin deposits and to compare them briefly with kaolins from Devon and Cornwall.

CZECH KAOLIN DEPOSITS

General

The production of kaolin from Czech deposits, geological host rocks and major markets served are shown in Table 1. Kaolin is the most important industrial mineral from the Czech Republic (Kuzvart, 1981).

Sedimental), kaolins - Pilsen area

The area to the north and south of Pilsen is part of a large basin into which thick sequences of sediments of Carboniferous age (Westphalian D to Stephanian) were deposited. The Pilsen Permo-Carboniferous basin was formed as a distinct graben trending roughly north-south during the Variscan orogeny. At the ZKZ deposits of Kasnejov and Horni Briza (Figure 2) the parent rocks of the kaolin deposits are believed by Kuzvart (1969) to be arkoses, arkosic sandstones and conglomerates. Kuzvart proposed that the kaolinisation of feldspars within the arkosic sandstone took place *in situ* during weathering, while Jiranek (1976; 1977) demonstrates that much of the kaolinite was formed elsewhere and deposited in the basin as part of a kaolinitic sand. There is little evidence that the degree of kaolinisation decreases with depth, as is often found in a weathering profile. The depth of kaolinisation reaches at least 90 m at Kaznejov and 80 to 110 m at Horni Briza. The clay deposits are selectively dry mined, based on kaolin brightness and chemistry, and processed to produce a wide range of products for paper coating (9%), paper filler (54%) and glass fibre and ceramics (37%). The yield of clay from the kaolinitic sands and kaolinitic conglomerates varies from 15 to 20% and much of the sand is sold for use in insulation blocks, concrete and in the construction industry.

At Chlumcany (Figure 2) the *Chlumcanske Keramicke Zavody (CKZ)* company has a factory which produces high quality floor tiles, refractories and also 36,000 tpa of a filler clay. The deposit is a sequence of Carboniferous (Westphalian) sands and arkosic sandstones which have been kaolinised *in situ.* The profiles show kaolinisation of the arkose down to 25 m in depth. Knapp *et* al. (1968) believed the kaolinisation was formed by alteration of the arkoses during Carboniferous times, though a subsequent phase, probably Palaeogene in age, giving rise to increased kaolinisation at the surface decreasing downwards, cannot be ruled out.

Sedimentary kaolin - Podborany area

The deposit of Krasny Dvur, near Podborany (Figure 1) produces approximately 24,000 tpa of kaolin for ceramics. The clay is processed at the nearby Hlubany plant and is mainly exported to Germany. The deposit consists of kaolinised arkosic sandstones of Permo-Carboniferous age. Kaolin was produced by weathering of the arkosic sandstones with the degree of kaolinisation decreasing with depth Micky *et al.*, 1968).

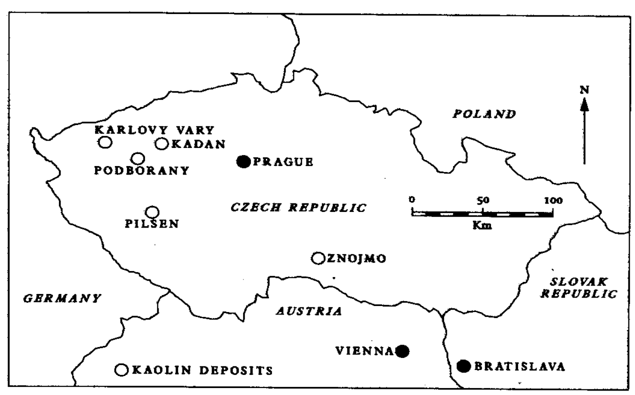

Figure 1. Location map of the main Czech Republic kaolin deposits

Kaolinised granites - Karlovy Vary region

The Karlovy Vary region is a classical area for kaolins used in the production of porcelain (Konta, 1974). In the area about 30 deposits of kaolin are known (Jiranek, 1990) and at the present time *KSB* has five operating pits and two plants in the Karlovy Vary area. The famous Sedlec (Zettlitiz) mine, now abandoned, from which high grade ceramic kaolins were produced, is just 2 km from Karlovy Vary (Figure 3). The kaolins from Osmosa, Podelsi, Hajek and Jimlikov are utilised in ceramics, while the Otovice kaolin is used as a paper filler clay (Table 1). The granites of the Karlovy Vary area are part of the Variscan Nejdek Granite Massif of the Krusne Hory Mountains (Bohemian Massif). The granite types and mineralisation have been extensively described and summarised (Breiter *et al.,* 1991; Stemprok, 1971; 1982). The Karlovy Vary area contains four main types of granite:

I. Horska (Mountain) - Older granites - mainly porphyritic biotite-granites,

II. Transitional types,

III. Krusne Hory (Ore Mountain) - Younger granites - *"Erzgebirge"* type - tin-bearing, topaz-biotite granites, and

IV. Lithium-bearing granites.

The granites have been subjected to weathering with alteration of the feldspar to kaolinite. The different granite types on kaolinisation exhibit variations in their accessory minerals (Konta, 1969) and trace element contents (Baburek, 1971). Proved depth of kaolinisation is more than 50 metres, but the commercially useful kaolin is found generally in the top 20 to 30 m. Three different zones of decomposition are recognized in the Karlovy Vary region:

I. Zone with all feldspar decomposed to clayey minerals

II. Zone where feldspar phenocryst centres remain unweathered, and

III. Zone where centres of feldspar grains of matrix remain unweathered.

The total porosity of the rock and organic content decreases with depth. The quality of the kaolin is very dependent on the parent granite composition, low iron types being derived from aplitic granites with little or no biotite (Baburek, 1970; Kukla, 1968; Kuzvart, 1969). The variations in petrography and geochemistry of the main parent kaolinised granites have been described by Neuzil and Konta (1965) with details of petrography of individual deposits given for Otovice (Baburek *et al.,*, 1959) and Jimlikov (Konta, 1975). Among the clay minerals kaolinite predominates, with minor amounts of illite (5%) increasing with depth. Montmorillonite is normally found in trace amounts at the base of the profile. Industrially two types of kaolin are distinguished on the basis of titania levels: one kaolin for porcelain has <0.4 wt.% TiO_2 and titania-bearing kaolins for other ceramics have between 0.4-0.7 wt.% TiO_2.

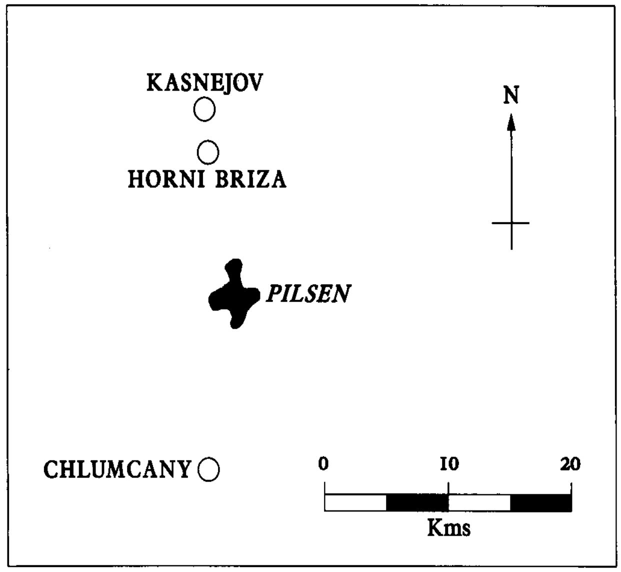

Figure 2. Location map of the kaolin deposits of the Pilsen Basin

Morphology of Czech kaolins

The sedimentary kaolins are generally well-formed pseudo-hexagonal platy kaolinites, while the kaolinised granites, though platy, do not show such well-formed crystals (Figure 4). More details on the morphology of Czech kaolins is presented elsewhere (Jiranek, 1990).

COMPARISONS WITH SOUTH-WEST ENGLAND KAOLINS

Paper Utilisation

80% of kaolin produced from Devon and Cornwall is utilised in paper as against 47% for the Czech Republic kaolin. Of the 80% of kaolin for paper from Devon and Cornwall the split is 50:50 between paper coating and filler. A coating clay must generally have a good brightness (>84 ISO), and low viscosity, with particle shape and size also an important factor (Adams, 1993). 47% of Czech kaolin produced is utilised as a filler clay and only 5% as a coating pigment (KKN 2 produced from the sedimentary kaolinitic sands of ZKZ) due to the low brightness of ISO 81. Compared with a coating clay from Cornwall (SPS) the Czech clay has significantly higher TiO_2, which gives rise to the poorer brightness (Table 2). The kaolinised granites from the Karlovy Vary region are not suitable for coating clay due to poor colour (high iron and titania levels) and the presence of some minerals (chlorite, illite and some montmorillonite) which cause poor rheology. However, both the kaolinised granite from Otovice pit (KSB) and the sedimentary kaolinitic sands *(ZKZ)* make suitable filler clay products. A comparison of some English and Czech coating and filler kaolins is shown in Table 2.

Area	Deposits	Tonnage (tpa)	Major Markets
	KAOLINISED GRANITES		
Karlovy Vary	Osmosa, Hajek, Podelsi, Jimlikov	109,000	Porcelain and Ceramics
	Otovice	36,000	Paper Filler
	Znojomo	20,000	Paper Filler
	KAOLINITIC SANDS AND ARKOSES		
Pilsen	Kasnejov and Horni Briza	345,000	Paper 63% Ceramics 37%
	Chlumcany	36,000	Paper filler
Podborany	Krasny Dvur	24,000	Ceramics
Krusna Hory	Kadan	10,000	Ceramics

Table 1. Czech kaolin production, host rock and utilisation for 1990.

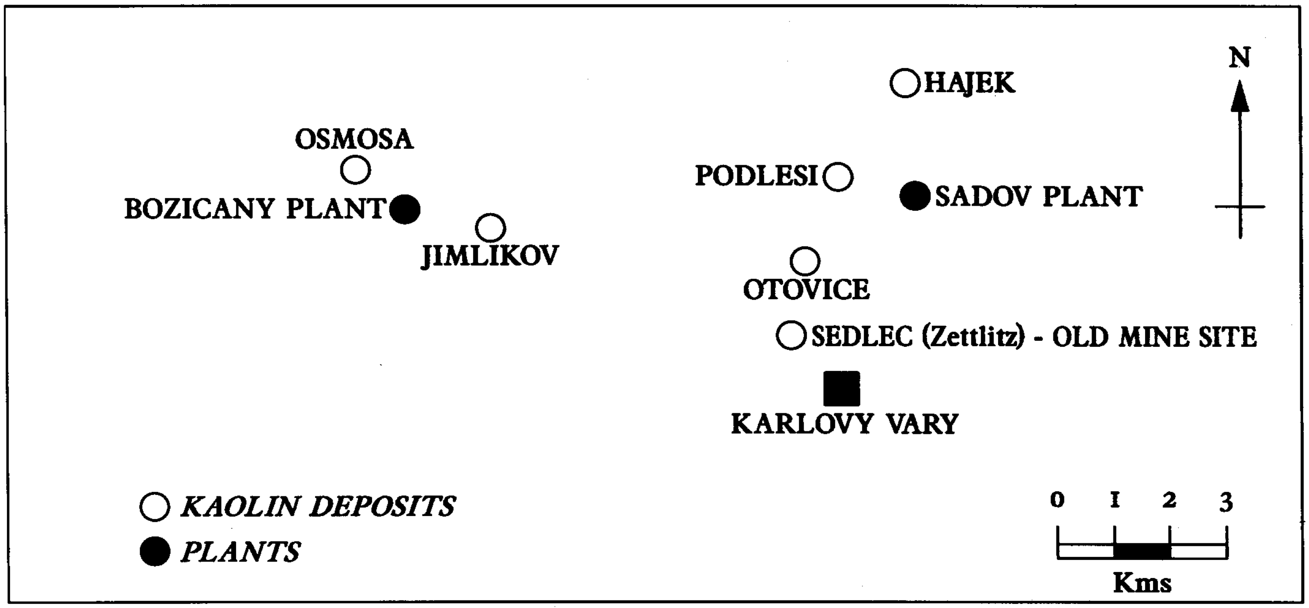

Figure 3. Location map of the kaolin deposits and plants of the Karlovy Vary Region

Company	ZKZ	ZKZ	KSB	ECCI	ECCI
Utilisation	Coating	Filler	Filler	Coating	Filler
Name of Product	KKN 2	Sp 87/F	Otovice 80	SPS	Grade B
Particle size					
wt.% >10 microns-	-	3	6	-	8
wt.% <2 microns	75	55	55	80	50
ISO Brightness (1)	81	80	78	85	82
ISO Yellowness (2)	6	6.3	6.5	4.5	5
Viscosity Conc (wt.%) (3)	68.1	-	-	69	67
Chemistry (wt.%)					
SiO_2	48	49	47	48	48
Al_2O_3	37	36	37	37	37
Fe_2O_3	0.5	0.47	1.3	0.58	0.8
TiO_2	0.6	0.52	0.57	0.03	0.04
CaO	0.12	0.09	0.07	0.04	0.06
MgO	0.14	0.14	0.26	0.16	0.2
K_2O	1.2	1.15	0.83	1.1	1.8
Na_2O	0.07	0.07	0.06	0.1	0.15
L.O.I.	12.7	12.5	13.1	13.1	12
Mineralogy (wt.%)					
Kaolinite	95	92	92	96	86
Mica	4	5	6	4	11
Quartz	1	3	tr	-	1
Others	-	-	2	-	2

(1) Brightness measured at an effective wavelength of 457 nm using a Zeiss Elrepho

(2) Yellowness is the difference between brightness measured against an effective wavelength of 570 nm and 457 nm.

(3) Viscosity concentration is the percentage by weight that gives a viscosity of 5 poise at 22°C.

Table 2. Quality of Czech paper coating and filler kaolins compared to south-west England paper kaolins

Ceramic Utilisation

Kaolins from the Karlovy Vary region produced by KSB have good ceramic properties, especially reasonable plasticity and casting properties with high strengths after drying, which contribute to the whiteness and transparency of the porcelain body after firing. The area has a long tradition of mining and processing of kaolin, leading to the recognition of Sedlec *(Zettlitz)* kaolin as a world standard of quality at the International Ceramic Congress at Copenhagen in 1924 (Konta, 1974). The old Sedlec mine is now abandoned, but a Sedlec *(Zettlitz)* grade is still produced by blending other clays from other mines along with other products such as *Imperial, Osmosa* and *Premier.* Among the many kaolin deposits in the Karlovy Vary area, the Jimlikov deposit yields ceramic kaolin of good quality, which by its chemical and mineralogical properties closely resembles the raw material from the classical Sedlec (Zettlitz) deposit (Konta, 1975). The Czech ceramic kaolins are similar to some Cornish grades (especially *Grolleg)* with the latter having a lower titania level but with similar strength and casting properties. *Super Standard Porcelain (SSP),* a kaolin produced in Devon, has a much lower iron level than *Grolleg* and the Czech clays but with lower titania which results in an excellent fired brightness. Both kaolinised granite from Cornwall and Devon and the Czech Republic produce kaolin for ceramics of high quality. Comparison of the *Sedlec (Zettlitiz) and ECG/* kaolins is shown in Table 3.

DISCUSSION

It is beyond the scope of this paper to discuss in detail comparisons between all kaolins from the Czech Republic and south-west England. However, a comparison can be made between the kaolinised granites of the Karlovy Vary and St. Austell areas (Table 4). The St. Austell granite, the most extensively kaolinised of the Cornubian batholith, shows distinct granite types (Exley, 1959; 1964; Dangerfield *et al.,* 1980; Hill and Manning, 1987). Various fluid inclusion studies indicate that the Sn-W mineralisation within the St. Austell and other granites was associated with high temperatures and salinities (Alderton and Rankin, 1983; Bristow, 1977; Jackson *et al.,* 1977; 1982; Jackson and Wilson, 1977). A recent review explains the genesis of the south-west England kaolins as a multi-stage story involving six major events from initial intrusion of the main batholith through to deep Mesozoic-Palaeogene weathering with a radiogenic-driven convective circulation of meteoric water producing the observed kaolinisation (Bristow, 1993). From the St. Austell granite, much of the high quality coating clay is derived from the lithium-mica granite (or globular quartz granite of Hill and Manning (1987)) which is low in iron content (no biotite). The best quality ceramic kaolin from the Karlovy Vary area is from those granites having a lower biotite content, with consequent lower iron and titania levels. However, kaolins derived from the dominant host biotite-granites in the Karlovy Vary area have limited its utilisation as a paper-coating clay, due to the poor colour (high iron and titania) and the presence of other clay minerals, causing poor rheology. A proper understanding of the host granites is the key to the quality of kaolin and the superb exposures afforded in the Devon and Cornwall kaolin pits enables detailed studies to be made by production and research geologists.

The Karlovy Vary kaolinised granites are less well exposed and are extensively faulted, compared to south-west England granites, making identification of original granite types more difficult. The Karlovy Vary kaolins are believed to have been formed by circulating meteoric waters in a supergene weathering environment (Konta, 1969; 1970). Whilst the south-west England kaolins are intimately associated with hydrothermal events, the low temperatures and salinities indicated by fluid inclusions are typical of a supergene weathering process. Stable isotope studies indicates that both the south-west England and Czech Republic kaolins are of weathering origin, probably being formed in a tropical to warm temperate climate (Savin and Epstein, 1970; Sheppard, 1977).

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Company	KSB	KSB	KSB	ECCI	ECCI
Name of Product	Sedlec/Zettlitz	Imperial	Premier	SSP	Grolleg
Particle size					
wt.% >10 microns	9	4	9	1	8
wt.% <2 microns	55	60	55	85	58
Modulus of Rupture	10	11	10	27	10
Casting data					
Casting Conc (wt.%)	58	57	58	58	61
P84	0.32	0.5	0.5	1.5	0.65
Casting Rate	0.84	0.73	0.84	0.35	0.7
Fired Properties 1280°C					
Brightness	91	81	92	96	84
Absorption	14	11	14	12	5
Contraction	10	11	9	10	14
Chemistry (wt.%)					
SiO2	48	48	48	47	48
Al2O3	37	37	37	38	37
Fe2O3	0.75	1.31	0.68	0.39	0.75
TiO2	0.21	0.09	0.2	0.03	0.02
CaO	0.08	0.07	0.08	0.1	0.06
MgO	0.24	0.27	0.23	0.22	0.3
K2O	0.95	1.32	0.92	0.8	1.85
Na2O	0.07	0.06	0.07	0.15	0.1
L.O.I.	12.9	12.4	12.9	13	12.2
Mineralogy (wt.%)					
Kaolinite	89	82	89	93	81
Mica	9	16	7	4	15
Quartz	1	tr	2	1	1
Others	1	2	2	2	3

Table 3. Quality of Czech kaolin for ceramics compared to south-west England kaolins

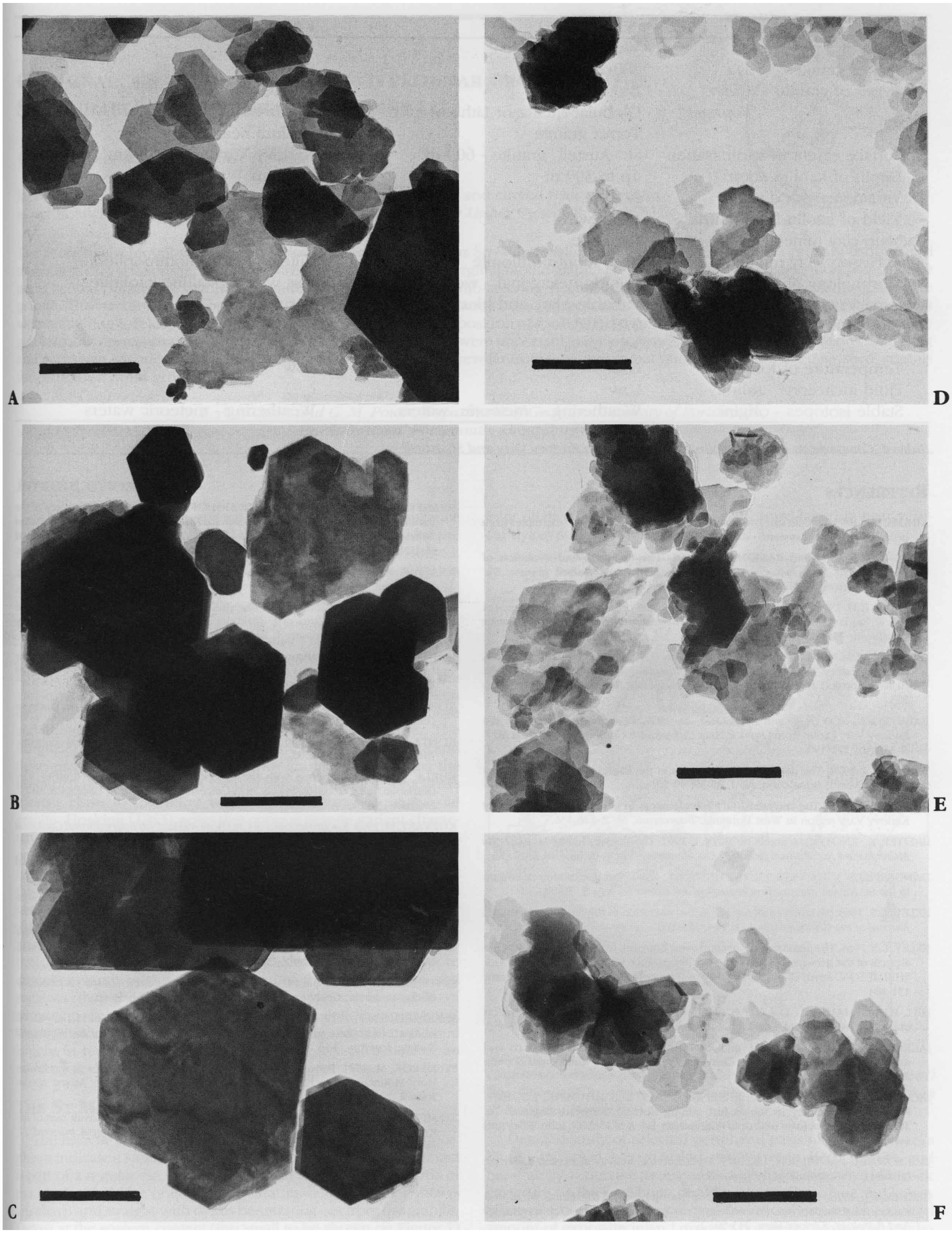

Figure 4. Transmission Electron Microscopy (TEM) of some Czech kaolins.

Bar scale on all photomicrographs = 1 µm. A - C. Sedimentary kaolins. (A) Well-formed pseudohexagonal platy kaolinite from kaolinitic sands of Kasnejov pit, ZKZ. (B) Euhedral platy kaolinite from arkosic sandstones of Chlumcany pit, CKZ. (C) Large euhedral platelets of kaolinite from arkosic sandstones of Krasny Dvur deposit, Podborany. D - F. Pseudohexagonal platy kaolinites (not so euhedral as sedimentary kaolins) from the Karlovy Vary kaolinised granites of KSB. (D) Zettlitz Premier grade ceramic kaolin. (E) Otovice filler clay. (F) Zettlitz/Sedlec 1A ceramic kaolin.

		ST. AUSTELL	KARLOVY VARY
Type of mining		Wet - monitor	Dry-diggers
Age of granites (M a)		280-290	307-320
Types of granite -	*"Older"*	Biotite-granite	Biotite-granite
	"Younger"	Globular-quartz or Lithium mica granite	Topaz-biotite granite
		Topaz granite	Lithium bearing granite
Surface extent of kaolinisation		St. Austell granite - 60 km^2	Karlovy Vary area - 85 km^2
Depth of kaolinisation		up to 300 m	40-50 m
Variations with depth		No	Decreasing kaolinisation
Yield of kaolin from matrix		15-20 wt.%	25-30 wt.%
Main clay mineral		Kaolinite	Kaolinite
Accessory clay minerals		trace-montmorillonite	Illite, chlorite, montmorillonite
Morphology of kaolinite		pseudo-hexagonal - well crystalline	less well crystalline kaolinite
Aspect ratio		Variable-platy and blocky clays	Variable
Chemistry	- TiO_2	0.01-0.03 wt.%	0.09-0.60 wt.%
	- Fe_2O_3	>0.3 wt.%	>0.5 wt.%
Temperature of formation		Low	Low
Fluid inclusions - salinity		Low	?
Stable isotopes - origin?		Weathering - meteoric waters	Weathering - meteoric waters

REFERENCES

ADAMS, J.M. 1993. Particle size and shape effects in materials science: examples from polymer and paper systems. *Clay Minerals,* **28,** 509-530.

ALDERTON, D.H.M. and RANKIN, A.H. 1983. The character and evolution of hydrothermal fluids associated with the kaolinized St Austell granite, SW England. *Journal of the Geological Society, London.* **140,** 297-309.

BRISTOW, C.M. 1977. A review of the evidence for the origin of the kaolin deposits in S. W. England. *In: Proceedings of the 8th International Symposium and Meeting on Alunite, Madrid-Rome*, 34-42.

BRISTOW, C.M. 1993. The genesis of the china clays of South-west England - A multistage story. In: *Kaolin Genesis and Utilization,* Eds: H.H. MURRAY, W.M. BUNDY and C.C. HARVEY. *The Clay Minerals Society, Boulder, Colorado,pp* 171-203.

BABUREK, J., KONTA, J. and SVOBODA, D. 1959. Petrographical study of the Karlovy Vary kaolin from Otovice. Acta *Universitatis Carolinae, Geologica No 1, 2. Prague*. 171-195.

BABUREK, J. 1970. The determination of zones in the kaolin deposits at Karlsbad (Karlovy Vary), *Interceram, No 1,* 35-36, 49-50.

BABUREK, J. 1971. The migration of trace elements in the kaolin profile of the Karlovy Vary region in West Bohemia. *Interceram, No 2,* 126-136.

BREITER, K., KNOTEK, M. and POKORNY, L. 1991. The Nejdek Granite Massif. *Folia Musei Rerum Naturalium Bohemia Occidentalia, Pilsen.* Geologica **33.** 1-32.

DANGERFIELD, J., HAWKES, J.R. and HUNT, E.C. 1980. The distribution of lithium in the St. Austell granite. *Proceedings of the Ussher Society,* **5**, 76-80.

EXLEY, C.S. 1959. Magmatic differentiation and alteration in the St. Austell granite. *Journal of the Geological Society,* **114,** 197-230.

EXLEY, CS. 1964. The granitic rocks of south west England. *In:* Present views of some aspects of the geology of Cornwall and Devon. Eds: K.F.G. HOSKING and G.J. SHRIMPTON. *Royal Geological Society of Cornwall 150th Anniversary Volume,* 131-184.

HILL, P.I. and MANNING, D.A.C. 1987. Multiple intrusions and pervasive alteration in the St. Austell granite, Cornwall. *Proceedings of the Ussher Society,* **6,** 447-453.

JACKSON, N.J., MOORE, J. McM. and RANKIN, A.H. 1977. Fluid inclusions and mineralizaton of Cligga Head, Cornwall. *Journal of the Geological Society*, London, **134,** 343-9.

JACKSON, N.J., HALLIDAY, A.N., SHEPPARD, S.M.F. and MITCHELL, J.G. 1982. Hydrothermal activity in the St Just mining district, Cornwall, England. *In: Metallization associated with acid magmatism.* Ed: A.M.EVANS, John Wiley and Sons, 137-79.

JACKSON, N.J. and WILSON, I.R. 1977. Hydrothermal activity at Bostraze clay pit (abstract). *Proceedings of the Ussher Soceity,* **4,** 11.

JIRANEK, J. 1976. Geological evidence of the genesis of the Homi Briza and Kaznejov kaolin deposits. *Proceedings of the 7th Conference on Clay Mineralogy and Petrology, Karlovy Vary*. 243-50.

JIRANEK, J. 1977. Geology, petrology and genesis of the kaolin sediments of the Horni Briza and Kaznejov in the Pilsen Basin. *Folia Musei Rerum Naturalium Bohemiae Occidentalis, Pilsen*. Geologica **8**. 1-34.

JIRANEK, J., MULLER, H.W. and SCHWAIGHOFER, B. 1990. Genetic types of the kaolin deposits in the Bohemian Massif. *In: Thirty years of geological cooperation between Austria and Czechoslovakia -Festive Volume.* Eds: D. MINARIKOVA and H. LOBITZER. Federal Geological Survey Vienna and Geological Survey, Prague.

KNAPP, R., KUZVART, M. and SINDELAR, J. 1968. The kaolin deposit at Chlumcany near Pilsen. *Acta Universitatis Carolinae, Geologica No 1,2, Prague.* 87-107.

KONTA, J. 1969. Comparison of the proofs of hydrothermal and supergene kaolinization in two area of Europe. In: *Proceedings of the International Clay Conference, Tokyo, Volume 1*, 281-290.

KONTA, J. 1970. Comparison of the proofs of hydrothermal and supergene kaolinization in two areas of Europe. In: *Proceedings of the International Clay Conference, Tokyo, Volume 2,* 91-93.

KONTA, J. 1974. The Karlovy Vary kaolin and its significance in the European ceramic industry. *Interceram, No 3,* 175-178.

KONTA, J. 1975. Raw kaolin from the Jimlikov deposits in West Bohemia. *Interceram*, No 4, 294-296.

KUKLA, J. 1968. Experience with the prospecting for kaolin the Karlovy Vary (Karlsbad) area, Czechoslovakia. *Acta Universitatis Carolinae, Geologica, No 1,2. Prague*. 139-149.

KUZVART, M. 1969. Kaolin deposits of Czechoslovakia. *13th International Geological Congress, Prague, Volume 15*, 47-73.

KUZVART, M. 1981. Industrial minerals and rocks in Czechoslovakia. *Industrial Minerals, March*, 29-32.

MILICKY, V., KRELINA, B. and KUZVART, M. 1968. Kaolin deposits in the environs of Podborany. *Acta Universitatis Carolinae, Geologica No 1,2. Prague*. 55-85.

NEUZIL, J. and KONTA, J. 1965. Petrology and geochemistry of the Karlovy Vary granite, the parent rock of the Sedlec kaolin. *Acta Universitatis Carolinae, Geologica. Supplementum 2, Prague*. 41.56.

SAVIN, S.M. and EPSTEIN, S. 1970. The oxygen and hydrogen isotope geochemistry of clay minerals. *Geochimica et Cosmochimica Acta,* **34**, 43-63.

SHEPPARD, S.M.F. 1977. The Cornubian batholith, SW England: D/H and $^{18}O/^{16}O$ studies of kaolinite and other alteration minerals. *Journal of the Geological Society, London.* **133,** 573-591.

STEMPROK, M. 1971. Petrochemical features of tin-bearing granites in the Krusne Hory Mountains, Czechoslovakia. *Society of Mining Geology of Japan, Special Issue* **2**, 112-118

STEMPROK, M. 1982. Petrology and geochemistry of the Czechoslovak part of the Krusne Horty Mountains granite pluton. Sbor. *geol. Ved, lozisk geol. mineral, 27 Prague, ISSN 0581-9180.* 111-156.