BRICK KILN FROM SW JUTLAND: THE KILN, HISTORICAL OUTLINE OF BRICK PRODUCTION AND FARM BUILDING IN JUTLAND, MAGNETIC AND LUMINESCENCE DATING OF THE KILN

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Abstract

The paper presents investigations of a brick kiln at Veldbæk east of Esbjerg excavated in connection with construction of a motorway. The kiln, a "farmers kiln", is described and the history of brick kiln construction and farm building in West Jutland is outlined. Magnetic and luminescence dating of the Veldbæk kiln are discussed and dating results presented. The magnetic and luminescence dates are 1790 ± 40 AD and 1795 ± 20 AD, respectively and these are in excellent agreement. A brick from one of the ash pits gave a luminescence date of 1550 ± 40 AD; this indicates that the brick was fired and used elsewhere prior to its use at Veldbæk.

Introduction

In Veldbæk just east of Esbjerg, Southwest Jutland, the remnants of a brick kiln was excavated in 1995 in connection with motorway construction. The kiln was situated among house sites from the medieval and renaissance periods and waste pits from the 18th century. All over the excavation area bricks of various sizes, including the large medieval bricks ("munkesten" in Danish) were found.

The procedure of brick production has not changed from the medieval period until the mid 19th century when the ring kiln was introduced at the industrialized tileworks. Nor has the construction of the kilns changed during the period mentioned although there are differences in how carefully the kilns are built depending on how many years and firings it was meant to last. The Veldbæk kiln was built to last for several years not as an industrialized tile-works, but for producing bricks for several farm buildings. (Fig. 1).

The only archaeological dating element was the stratigraphic placing of the kiln on top of a late medieval-early renaissance house site from ca 1600 AD. In order to get a more precise age of the kiln, magnetic and luminescence datings were carried out.

The construction of the Veldbæk brick kiln

The size of the central part of the Veldbæk brick kiln measured approximately 4.5 m E-W and 3.5 m N-S with firing from the east in two heat channels. The floor of the kiln and the southern heat channel were built of granitic stones while the northern heat channel was made partly of stones and partly of bricks. (Fig. 2).

The heat channels ended to the east in two ash pits with walls carefully built of stones except for the western wall in the southern pit which was built of bricks with mortar as cementing material. (Fig. 3).

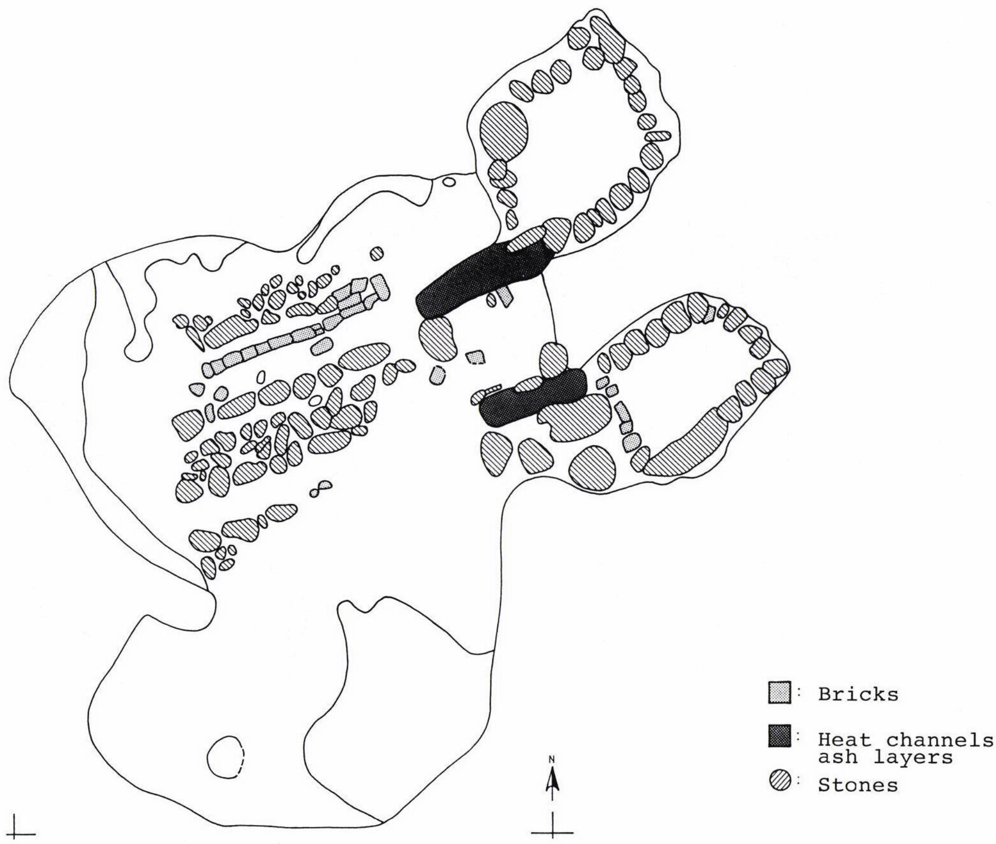

Fig. 1. Excavation map of the Veldbæk brick kiln 1:50 (Del.: Helle Lauridsen, Esbjerg Museum).

The stone-built kiln floor and heat channels and the carefully made ash pits are two very unusual features in the Veldbæk kiln. Traditionally, the floors, walls and heating channels were brick-built and ash pits – if there were any – usually consisted of a small pit in the ground.

The process of brick production

The small local brick kilns ("farmers' kilns") were placed close to the site where the bricks were being used. The production of bricks was usually done by a travelling brickmaker. The firing of the bricks took place during the summer due to the weather conditions, but the preparations for the brick production had been going on for about a year in advance. Firstly, heather turf for the firing was cut; it took at least one heather turf measuring 60 cm x 80 cm to fire one brick. The clay was dug up during the winter so that it could be made brittle by the frost (Hundebøl 1982).

The kneading yard where clay, water and, if necessary, sand were mixed to a suitable consistency was often placed near the brick kiln. In Veldbæk the kneading yard was paved with stones and circular with a diameter of 7 m. (Fig. 4). A kneading device e.g. a large wheel or a small two-wheeled cart was tied to a crossbar. Outside the

Fig. 2. The floor in the brick kiln with the two firing channels. (Photo: Ulla Mejdahl, Esbjerg Museum).

Fig. 3. The two unusual ash pits with stone- or brick-built walls. (Photo: Kasper H. Søsted, Esbjerg Museum).

Fig. 4. Circular and neatly paved kneading yard. (Photo: Anne B. Hansen, Esbjerg Museum).

paved kneading yard a horse pulled the crossbar round and round in circles until the clay was sufficiently kneaded.

When the clay had the right consistency it was shaped into bricks in a mould. The wooden moulds often contained two bricks and the brickmoulder was able to shape more than 3000 bricks per day. The dry bricks were stacked in the kiln. The first 3–4 days and nights the fire was very low and the remaining moisture was driven out of the bricks. When properly dried, the bricks were fired at a powerful and steady blazing fire for some days and nights.

Inside the kiln not all bricks were evenly heated. The hard and well fired bricks were used for the outside walls while the soft and not so well heated bricks were used inside the houses as partition walls. The very hardfired bricks which sintered together were discarded.

Several firings had to be made before enough bricks for building a farm were produced, and the brick production for each farm often took more than one summer. Several years might pass from the decision to build a farm was made until the actual process of building could begin.

Historical background

In Denmark, from the end of the 12th century, bricks were produced and used for building castles, monasteries, churches, cathedrals and similar prominent structures (Koch 1973). Ordinary houses and farms were made in half-timbering with roof- and wall-bearing constructions based on posts dug into the ground.

As early as Medieval times Denmark did not grow enough forest to be self-sufficient with building timber and timber had to be imported from Norway and the Baltic countries. In 1554 the lack of timber made the King prohibit the use of posts dug into the ground in Jutland because these posts would rot faster than posts placed on a stone foundation or in a "footholder" ("fodrem" in Danish) and thereby lead to a larger consumption of wood (Vensild 1994). The prohibition was not obeyed in spite of several repeats. Firstly, the disobedience was due to the long distance between the King in Copenhagen and the farmers in Jutland. Secondly, building traditions played a major role, for centuries, even millenniums the posts were dug into the ground and traditions do not change overnight, particularly not in western Jutland where the ground is very poor on stones suitable for a stone foundation. Even more so, the farmers in West Jutland owned their farmbuildings, in contrast with farmers in the rest of Denmark, whose houses were owned by the landowners, who could command changings in building tradition if they wanted to.

The procurement of building material became much easier when the Danish Law of King Christian V in 1683 gave permission for everyone to produce bricks. The tradition of local brick production and brick-built houses spread during the late 17th century from the Netherlands through Germany and the western parts of South Jutland, finally reaching the northern parts of the Danish marsh areas around Esbjerg in the late 18th century (Dragsbo 1985). In 1838 in Ribe County alone 243 local brick kilns existed which was half the total number of all brick kilns in Denmark (Videbæk 1980). It was also in these parts of the country, poor in forest and close to the marsh, that brick-built houses had the largest extension in the 19th century while the houses in the rest of the country still were made in half-timbering (Zangenberg 1925).

The subsoil in West Jutland consists mostly of melt-water sands with very small and sparse clay deposits. It may seem odd that this part of Denmark with no forest usable as firing wood and hardly any clay for moulding bricks is the part of the country where brick-built houses were most common. This is due to the heather moor, which delivered lots of turfs for the firing and the marsh with thick layers of adhesive clay usable as raw material for the bricks.

Even late in the present century, it was still believed that farmers in West Jutland lived a poor and miserable life before 1800 because their farming was based on animal production rather than crop growing. This history understanding was rooted around 1750 when cereal export began to play a very important role in the national economy, and this resulted in large agricultural reforms. One of the main reasons for the agricultural reforms was the need of increasing the production of cereal in order to satisfy the increase in cereal export. One of the methods to extend the cereal production and therefore an aim of the reforms was to improve the life conditions of the copyholders in order to make them cultivate new land (Henningsen 1995).

The agricultural reforms had large consequences in West Jutland because great effort was put into transforming the heather moor into wavy wheat fields. The new land registration required building of new farms which lead to a building boom in West Jutland in 1790–1819 when the first brick-built houses were raised and home-made bricks used.

But the historical interpretation of the marsh and moor farmer as being poor is not correct. On the contrary, many farmers in West Jutland were better off than the rest of the farmer community in Denmark before 1800. This was due to the long distance between West Jutland and the more "civilized" parts of the country. Tax collection was rare in West Jutland mainly because taxes were related to cereal production which hardly occurred in this area. Only rye was profitable to grow. Secondly, it was very unpleasant and to some extent dangerous for the tax collector to travel in the moor

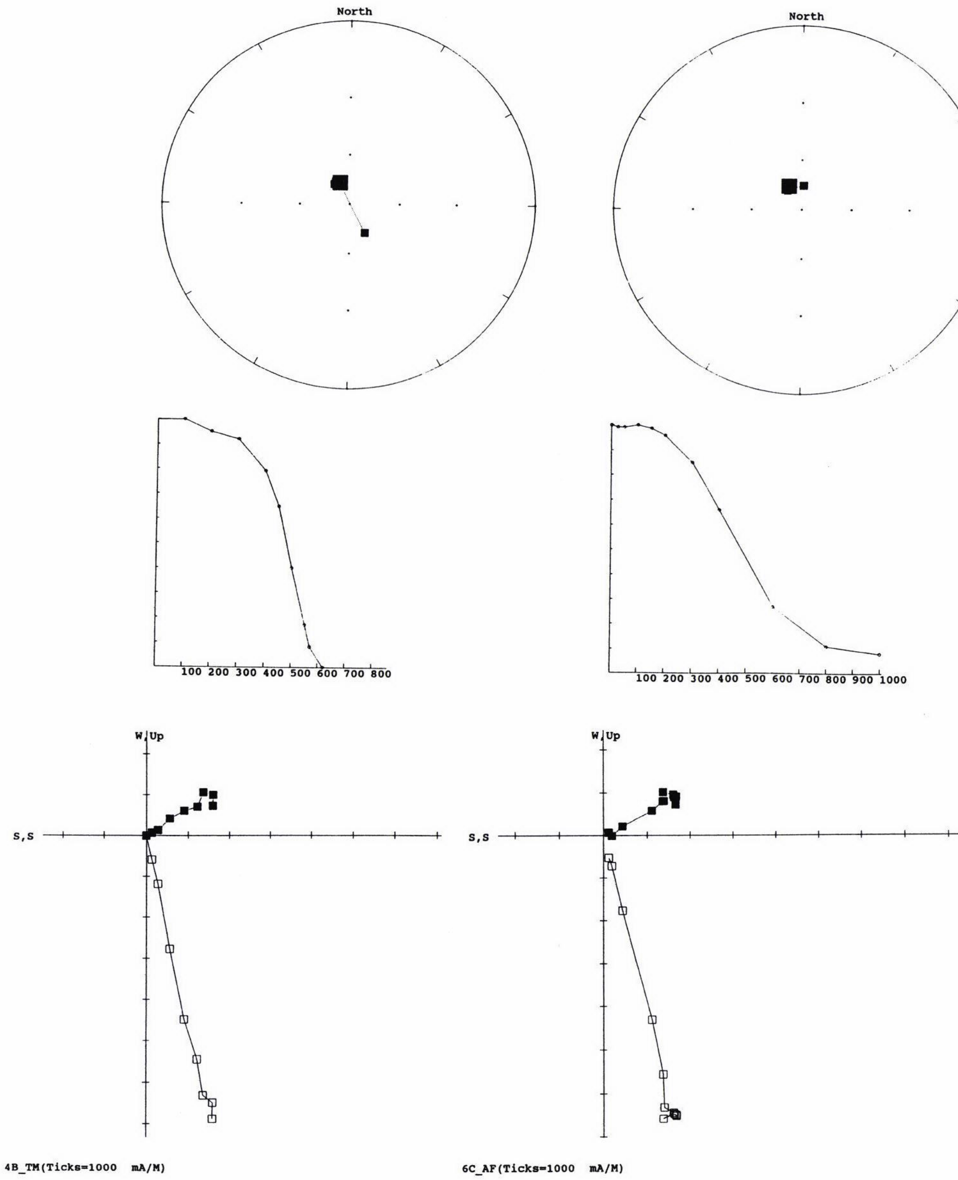

Fig. 5. Representative examples of demagnetization experiments (stereogramme and intensity decay) by thermal- (specimen 4B) and alternating field- (specimen 6C) demagnetizations, respectively. Specimen 4B shows a Curie-temperature of 580° C, indicating the dominating magnetic carrier to be pure magnetite, which is confirmed by the typical AF-decay of the intensity of specimen 6C.

areas. The distance between inns was large and the farmers were obviously not very friendly towards the tax collector. The low taxes and good prices on pottery, wool, butter and, not least, on honey together with a black economy based on smuggling steers across the Kongeå river between Esbjerg and Ribe made many farmers relatively rich (Henningsen 1995). Historical source material from ca 1550 tells us that many peasants from the marsh areas in South-west Jutland were rather well off. They

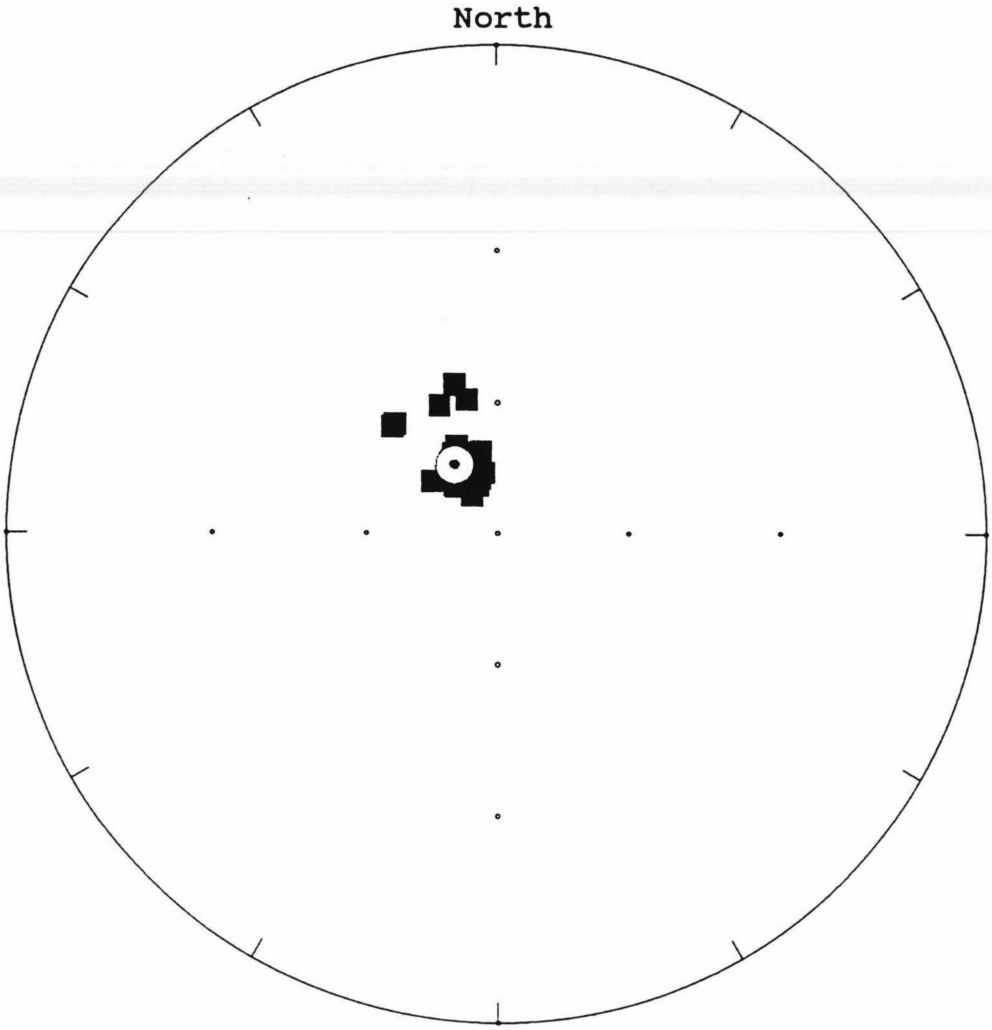

Fig. 6. Characteristic directions of the cleaned NRM of 39 specimens. Mean direction is (D_m, I_m) = (331°, 73.7°) with the α_{95}=2.0° (radius of confidence circle of 95% significance). Precision parameter is k=131, sum of unit vectors R=38.7103 (stereographic projection).

could actually afford to buy smaller loads of bricks from the industrialized tileworks near Haderslev in Southeast Jutland (Poulsen, in press). The bricks were used for building baking ovens, chimneys and walls in the wells. Like all other building materials, the bricks were reused the following 2–300 years until the production of bricks became a possibility for everyone (Mejdahl, U. 1996).

Magnetic dating

Only parts of the kiln floor and minor parts of walls were preserved, but since the structure was undisturbed it was decided to use the magnetic method for dating. Magnetic dating has earlier given good results for Danish kilns (Abrahamsen 1984, 1991; Abrahamsen & Skaarup 1994).

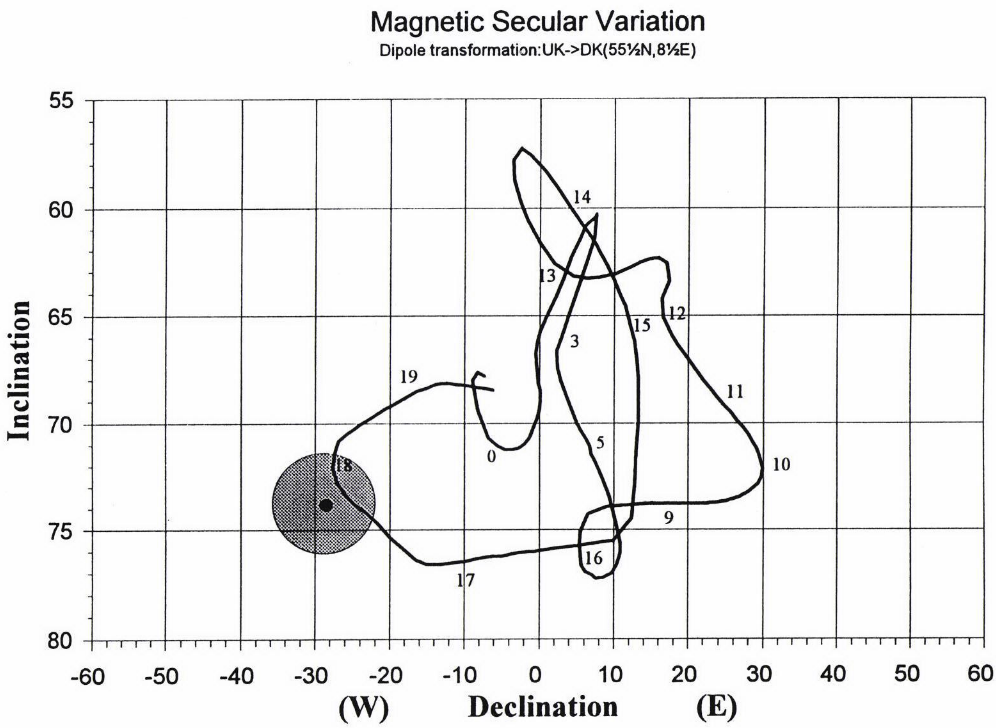

Fig. 7. Magnetic dating of the Veldbæk kiln by means of the geomagnetic secular variation. The curve shows the geomagnetic secular variation in SW Denmark, dipole-transformed from British data (Clark et al. 1988; Abrahamsen 1996). Numbers indicate century AD. With a magnetic mean direction of (D_m, I_m) = (331°, 73.7°) and α_{95}=2.0°, we find a magnetic age of about 1790 AD ± 40 y.

Principle of magnetic dating

Remanent magnetization. Magnetic properties of a ferromagnetic material are determined by the remanent magnetization NRM and the magnetic susceptibility k. The ratio between the remanence NRM and the induced magnetization J_i=k·T is the so-called Q-ratio, Q=NRM/J_i (T being the total geomagnetic field). If Q is high, the magnetic memory is likely to be more stable, and the material likely to be suitable for magnetic dating (Abrahamsen 1984). Although variable between 3.6 and 25, the average value of Q was 10, and thus the remanent magnetization NRM is strongly dominating over the susceptibility, and furthermore the demagnetization experiments (Fig. 5) show the direction of the remanence to be very stable.

Magnetic age. A number of 39 specimens taken from the kiln floor were investigated. Characteristic examples of thermal and alternating-field (AF) demagnetizations are illustrated in Fig. 5. All specimens show Curie-points around 580° C, indicating the dominant magnetic carrier to be pure magnetite, which is also supported by the bell-shaped decay curve by the AF demagnetization; the median destructive field is around 40 mT.

The directions of the cleaned NRM values are shown in Fig. 6. Spherical statistics (Fisher 1953, Butler 1992), give a mean direction of (D_m, I_m) = (331°, 73.7°) with α_{95}=2.0° (radius of 95% significance circle), precision parameter k=131, and the sum of unit vectors R=38.7103. By comparison with the magnetic master curve (Fig. 7) for secular variation in the area (Abrahamsen 1972, 1996), the kiln may then be magnetically dated. The magnetic age (being the age for the last cooling of the heated kiln material) is seen to be around 1790 AD ± 40 y.

Discussion and conclusions of the magnetic dating

The age of the kiln was originally expected, for archaeological reasons, to be around 1500–1600 AD. If so, the magnetic direction found could only be obtained by a physical disturbance in form of a counterclockwise rotation of some 30–40° of the whole kiln, which was difficult to understand and accept. If (for some unknown reason) the magnetic declination was not reliable, the magnetic inclination could still have been used for magnetic dating. In this case two dates would be possible for the Veldbæk kiln, either second half of the 16th century, or the late 17th century, when the inclination was around 74° (cf. Fig. 7). Older dates between 500 and 1000 AD would not have been relevant in this case, as the technique of using fired tile bricks were not applied in Denmark before around 1160 AD (Brøndsted 1961, Koch 1973, Abrahamsen 1992).

Fortunately, the kiln was also sampled for luminescence dating. The luminescence measurements gave an age of 1795±20 AD. The two dating results therefore support each other very well, and the initial archaeological expectation of an older age may be discarded.

Studies of local literature (Ulla Mejdahl, see above) have recently confirmed, that in the SW part of Jutland there was a boom in the building activities in two periods, between 1790–1819 AD and 1860–70 AD, during which it became much more common than earlier to use fired bricks for buildings in this area. The elder of these two historically evidenced periods thus is in excellent harmony with as well the magnetic as the luminescence dates.

Luminescence dating

Luminescence dating includes two dating methods: Thermoluminescence (TL) and optically stimulated luminescence (OSL). The methods have the same basis, namely that quartz and feldspar minerals in the material absorb radiative energy when they are exposed to ionizing radiation (alpha, beta and gamma). The stored energy can be released as a luminescence signal by heating the minerals to a temperature of 500°C or more (TL) or exposing them to green or infrared light (OSL, Bøtter-Jensen and Duller, 1992). When archaeological materials are exposed in nature to the natural background radiation (from uranium, thorium and potassium and cosmic radiation), the luminescence emitted is a measure of the time elapsed since a past zeroing event which for archaeological materials is the firing or the latest heating to a temperature of 500°C. The luminescence signal is converted to radiation dose by comparison with the signals released from mineral portions that have been irradiated in the laboratory with known doses. When also the annual dose has been measured, the age can be calculated from the following equation:

Age = Accumulated dose/Annual dose.

Methods for determining the accumulated and annual doses have been described by Aitken (1985). Mejdahl (1990) has discussed the various dose components and measurement uncertainties.

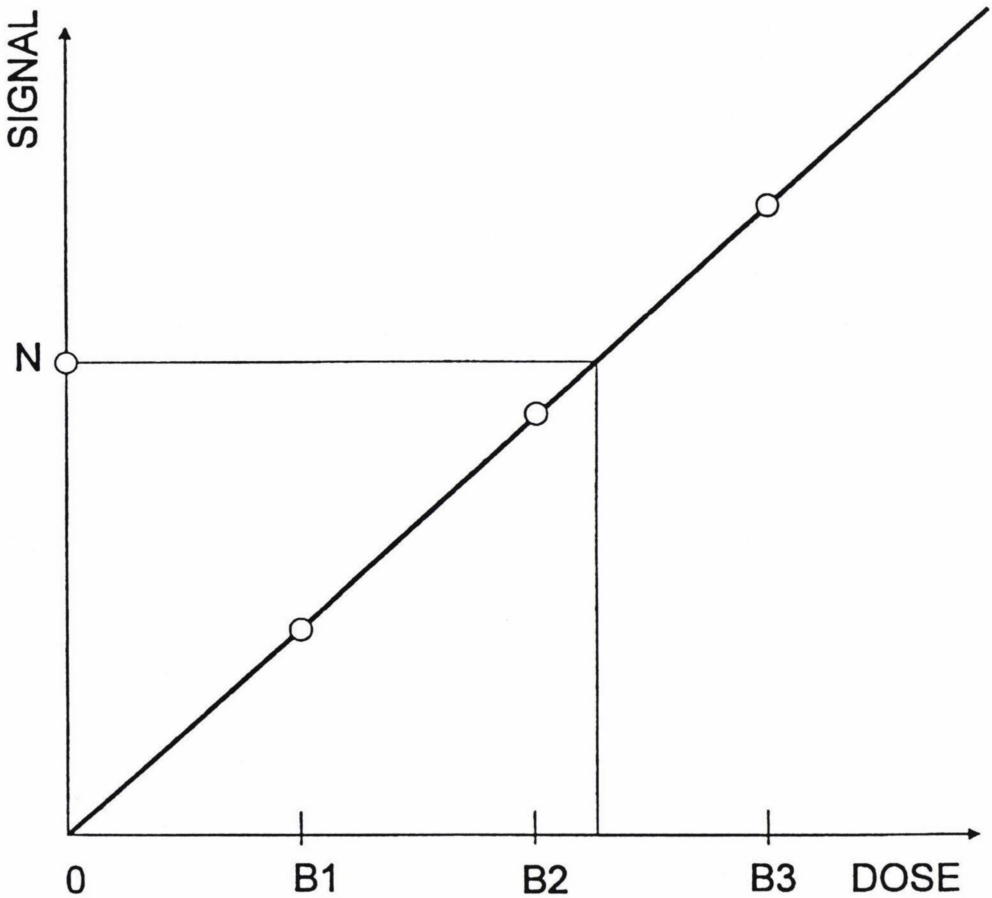

Fig. 8. Principle of the regeneration method for determining the accumulated dose.

Two samples, a brick from the southern firing pit and a granitic stone from the southern heat channel were dated by luminescence. The dating was based on the OSL method SARA (Single Aliquot Regeneration Added Dose). The method uses the regeneration technique in an added dose frame. The signal is regenerated by irradiating mineral samples that have been zeroed in the laboratory with a series of beta doses. The natural signal is then compared with the signals resulting from these known doses and the dose that gives a signal equal to the natural signal is equal to the accumulated dose (Fig. 8). The SARA method was proposed by Mejdahl and Bøtter-Jensen (1994). The technique is not described further here, but reference is made to Mejdahl (1993) and (1996). The method uses the "single aliquot" principle (Duller 1991) in which the accumulated dose can be determined from one single 10 mg portion (aliquot). SARA is not quite a single aliquot method because it requires at least three aliquots, but it has the advantages of single aliquot dating:

(1) Very small samples can be dated.
(2) The measurement precision is high, 3–4%.
(3) No normalisation of signals is required as is the case when a larger number of aliquots (usually 24) is used.

An important property of the SARA method is that it eliminates a serious source of error in the regeneration technique namely the change in sensitivity to radiation that often occurs during laboratory zeroing of the luminescence signal.

The dating was based on quartz separated by the heavy liquid technique (Aitken, 1985; Mejdahl, 1988). The grain size was 0.3–0.5 mm. Dose rate data are given in Table 1 and the dates for the brick and the stone are listed in Tables 2 and 3, respectively.

The luminescence date of the granitic stone, 1795 ± 20 AD, is in excellent agreement with the archaeomagnetic date, 1790 ± 40 AD. The luminescence date for the brick, 1540 ± 40 AD shows that it apparently was not heated sufficiently in the firing pit to reset the luminescence signal. The higher age indicates that the brick was fired and used somewhere else before it was reused as part of the construction of the firing pit.

Conclusion

The magnetic dating result 1790 ± 40 AD for bricks and the OSL date 1795 ± 20 AD for a burnt stone from the firing channel match each other perfectly and are supported by the historical evidence of the agricultural reforms leading to a boom in brick-built houses in South-west Jutland in 1790–1810.

A brick from the wall in one of the ash pits gave an OSL dating results of 1550 ± 40 AD. This was at first a very surprising result, especially because the firing chan-

Table 1. Dose rate (Gy/ka) for the two quartz samples from a brick and a granitic stone from the kiln at Veldbæk. The beta radiation was corrected for water absorption and grain attenuation and an alpha effectiveness factor of 0.10 was used (Nambi and Aitken 1986).

Lab. No.	Sample	Water Content (%)	Gamma + Cosmic	Beta	Alpha (1)	Total
R-952036	Brick	15.6	0.65	2.05	0.13	2.83 ± 0.10
R-952037	Stone	2.4	0.60	2.67	0.13	3.40 ± 0.13

(1) From U and Th embedded in the crystals.

Table 2. Luminescence dates for quartz samples extracted from a brick from the brick kiln at Veldbæk. The brick was taken from the southern firing pit. The dating was based on the SARA OSL method. The correlation coefficient (Cor) for the added dose plot is given.

Lab. No.	Sample	Run No.	(Cor)	SARA Age (years)
R-952036	Brick	CG6042	0.980	360
”	”	CG6057	0.985	481
”	”	CG6059	0.993	382
”	”	CG6061	0.961	553
”	”	CG6116	0.965	555
	Mean value		466 ±40 years	
	Standard deviation		17.7%	
	Statistical mean error		7.9%	
	SARA date		1540 ± 40 AD	

Table 3. Luminescence dates for quartz samples extracted from a granitic stone from the brick kiln in Veldbæk. The stone was found in the southern heat channel. The dating was based on the SARA OSL method. The correlation coefficient (Cor) for the added dose plot is given.

Lab. No.	Sample	Run No.	(Cor)	SARA age (years)
R-952037	Stone	DG6042	0.999	185 ± 20
"	"	DG6045	1.000	221 ± 20
"	"	DG6062	1.000	227 ± 20
"	"	DG6066	1.000	172 ± 20
	Mean value		201 years	
	Standard deviation		11.6%	
	Statistical mean error		5.8%	
	SARA date		1795 ± 20 AD	

nels and the ash pits clearly belonged to the same kiln construction and therefore similar dates for the two features were expected. But subsequent studies of the history of West Jutland showed that farmers in 1550 actually bought bricks from the industrialized tileworks. Bricks is a long-lasting material and it is very likely that they, like all other building materials, were reused again and again. The OSL result therefore underlines the new trends in the interpretation of the history of West Jutland.

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