TOWARDS RADIOCARBON CHRONOLOGY OF THE INCA STATE

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SUMMARY: This paper is dedicated to consider a problem of possibility of C-14 method application to establish the Inca state chronology. We attempted to find out the time intervals of Inca Imperial Phase and Inca Preimperial Phase and to make rough estimation of time intervals corresponding to periods, when succeeding rulers of The Inca Empire reign. To this end we made use of composite probability distribution of calibrated radiocarbon dates. Obtained results seems to confirm time intervals established basing on the chronicles.

Introduction

The Inca State chronology, existing till now and widely accepted, was established on the grounds of the historical sources, particularly on the chronicles of Pedro Cieza de Leon ("El Senorio del los Incas" and "La Cronica del Peru"), Juan de Betanzos ("Summa y narracion de los Incas"), Bartolome de las Casas ("Apologetica Historia"), and Miguel Cabello de Valboa ("Miscelanea Antarctica"). However this chronology is still an object of controversies between the scholars. The causes for it are as follows:
- on the one hand the Inca did not leave us any written sources on this matter.
- on the other hand the signification of the information contained in the chronicles is not clear and univocal.
These controversies may by solved only by independent archaeological methods. This paper consider a possibility of application of C-14 method to establish the Inca state chronology.

Chronology of the Inca State

The equivocality of historical sources resulted in the rise of two general chronological conceptions, so called schools. The first one, called historical, treats the information contained in the chronicles, particularly the Miguel Cabello de Valboa one, as a record of Inca history. So consequently the list of the Kings cited therein can be considered to be good approximation of the Inca past, assuming that it is complete. The scholars belonged to this school agree that Inca history divide into two phases: preimperial (local) and imperial. From it they derive two chronological models. The first one (elaborated by J.H. Rowe) assumes that in the Inca Kingdom reigned monarchy, so the rulers form the list of Kings succeeded each other

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(see Appendix 2). According to the second model, called diarchical, in Cuzco governed simultaneously two dynasties: one of the Hurin and the other of the Hanan Cuzco (see Appendix 2). As a result of its the length of the preimperial phase would be shorter by a half in comparison with the first model. However lack of sufficient number of ethnological evidence do not permit us to declare in favour of one of these conceptions and it is reasonable to leave the problem of diarchy opened.

The second school, called anthropological school of R.T. Zuidema (author of the second models cited above), treated whole Inca history presented in the chronicles, up to Spanish conquest as a myth (Zuidema 1964; 1982). According to it, the chronology should be established independently by archaeology and its methods.

The most widely accepted version of Inca chronology locates the beginnings of their state about 1200 AD (J.H. Rowe 1945; 1963). From 1200 to 1438 AD the Incas was a small tribe, which lived in the neighbourhood of Cuzco. This period is called Preimperial Phase. The Imperial Phase began with reign of Pachakuti Inca Yupanqui - ca 1438 AD and terminated in 1537-1539 AD with Manco Inca withdrawal to Vilcabamba. This period is commonly considered to be the end of Inca Empire because by then the whole Inca administration functioned although the Spaniards controlled the greater part of empire. Pachacuti Inca Yupanqui spread his empire over the highlands from lake Titicaca in the south to more or less lake Junin in the north. About 1463 AD, as it is supposed, the command of army was delivered to his son - Topa Inca Yupanqui, who invaded the area from Quito northwards to Pacacamac in the Central coast of Peru, including the states Cajamarca and Chimu. When Topa Inca came to the throne, he carried on the territorial expansion up to his death about 1493 AD, submitting the west part of actual Bolivia, north-west Argentina and Chile and fixing the southern boundary of empire on the Maule (Maipe) river. His successor - Huayna Capac (1493-1528) conquered significant part of Ecuadorion highlands from Quito to Ancasmayo river. Huascar Inca and Atahuallpa - sons of Huayna Capac - incorporated only small territories (Huascar incorporated Pasto region, Atahuallpa - Chachapoyas).

State of archaeological investigations

The archaeological investigations have been conduced in all Tawantinsuyu territory, but degree of its advancing is different in particular countries formed ancient Inca Empire. In Ecuador there is a little number of radiocarbon dates coming from Inca sites with good established stratigraphy, because the information comprised in the chronicles has been considered to be sufficient to solve chronological problems. As regard to the territory of Chile, Bolivia and Argentina there are some radiocarbon dates but in general, the investigations on this matter are little advanced. Only in Peru the state of archaeological research, including application of C-14 method is satisfactory.

It is important to point that the great part of excavations in the Inca sites is concentrated on Imperial Phase, because the cultural markers of this phase, contrary to the preimperial one, are well defined. J. H. Rowe indeed set forth the conception to identify the Killke culture with the Inca Preimperial Phase, but there is lack of sufficient number of archaeological research with enough good stratigraphy, which could confirm or deny it. This theory was built basing on stratigraphy of Sacsayhuaman, one of the most famous Inca site. In the main site the Killke ceramic was found under surface level, where it occurred mixed with Inca classic ceramic. The Killke culture differs from other ones only in ceramic, which forms are intermediate between Tiahuanaco and Inca. However the architecture pertained to this culture is constructed in the pirca technique. This arguments in our opinion seem to be not sufficient to identify it with Inca Preimperial Phase. We do not know after all, whether main culture

belongs in fact to Inca or to another tribe group, which lived in Cuzco area at the same time. Consequently, if radiocarbon dates come from architecture built in the pirca technique we can be in doubt if they pertain to Inca or another group. To assume attitude towards this question we need more archaeological research with good stratigraphy.

Moreover it is worth to point, that the archaeologists writing about cultural attachment of the site "Inca" mean by this "Inca Imperial Phase", so it is difficult to establish chronology for earlier phase basing only on this information. Besides we do not know exactly when the appearing artefact features, characteristics for Inca imperial phase begun, what would be important with estimation of radiocarbon dates attached to the turn of Preimperial Phase.

Another problem is attachment of a concrete territory to The Inca Empire, basing only on archaeological evidence, because presence of Inca material could indicate Inca occupation as well as to be a result of trade with independent tribe. Moreover there are any visual changes in Inca artefacts during the period of expansion, what makes difficult to distinguish reign of successive rulers.

Despite these problems we decided to assume in our analysis that the appearance of the artefacts characteristic for Imperial Phase started in beginnings of this phase and the presence of the Inca material indicates their occupation of concrete territory.

Problems of interpretation of calibrated radiocarbon dates

One of the basis of the radiocarbon dating is the fundamental hypothesis that the concentration of ^{14}C at biosphere has remained constant during the past 100,000 years. However, with the increase of the accuracy of dating, it was realised that this hypothesis is not precisely true, and concentration of ^{14}C has been variable during the past. Systematic studies of discrepancies between radiocarbon and calendar dates, based on accurate radiocarbon determinations in dendrochronologically dated tree-ring samples have led to publication of numerous versions of calibration curves and tables. Finally, the high precision calibration curves, accepted by the participants of the 12th International Radiocarbon Conference in Trondheim in 1985, have been published. Since then the conversion of radiocarbon dates to calendar time-scale has become possible. In 1993 the new, corrected version of calibration curve have been published in the special number of journal "Radiocarbon" (Fig.1). However, practical application of those high-precision calibration curves is not simple. Because of numerous wiggles of calibration curve the correspondence between conventional radiocarbon dates and calendar ages is not univocal - there can be several values of calendar age corresponding to a given radiocarbon date. In order to overcome the difficulties caused by multiple intercepts with calibration curve the concept of probabilistic calibration of radiocarbon dates was introduced and developed together with a set of appropriate computer procedures for performing this calibration.

Probabilistic character of a result of radiocarbon measurement is integrally relevant to the nature of radioactive material decay. Due to this nature and random variation during measurement process several concurrent analyses produce statistical spread of obtained radiocarbon dates. The radiocarbon age expressed as a mean and standard error is a convenient summary of this statistical spread assumed to be Gaussian distribution (with familiar "bell-shape"). The idea of probabilistic calibration consist of making a transformation of initial probability distribution of conventional radiocarbon age into final probability distribution of calendar age. After conversion of likelihood distribution of radiocarbon age, using calibration curve, to appropriate probability distribution of calendar age we can obtain various shapes of the latter. The simplest example we may obtain is likelihood distribution of calendar age looking like Gaussian distribution. More complex example we may obtain is

presented in Figure 2. After performing the calibration procedure with e.g. radiocarbon date 710±55 BP (from Pumamarca site) we obtain two clearly separated modes (peaks). We can assume, that obtained two possible calendar dates with probability given by the area under each peak. The base for such interpretation is the nature of calibration curve (samples with different calendar dates may give the same result of radiocarbon measurement - same radiocarbon age). At our example we obtained the date about 1290 AD with likelihood 65% and the date about 1370 with likelihood 35%. Unfortunately it is impossible to choose which of them is real age of sample using radiocarbon data only, but we may do it by use extra information.

Analysis of the gathered dates

Radiocarbon dates analysed below are divided, according to their provenience, into two parts: dates from architecture and dates from artefacts. The dates derive for the most part from Peru (44) and besides from Chile (2), Argentina (2) and Ecuador (2). All dates were calibrated using the Gliwice Calibration Program GdCALIB ver.6.0 (Pazdur & Michczyńska 1989). The calibration curves used for the calculation were taken from "Radiocarbon" - "Calibration 1993" (Stuiver, Long and Kra, 1993). We decided to calibrate the dates without correction for systematic age difference between northern and southern hemisphere, which was estimated to be about 40 years (Vogel *et al.*, 1993). The value of this correction was obtained for wood samples from South Africa (latitude between 25°S and 35°S). We are of the opinion that this value may be not valid for almost strictly equatorial region. Figure 3 shows probability distributions obtained as a result of the calibration, whereas a short analysis of these distributions together with analysis of archaeological context are presented below (Table 1, Table 2).

TABLE 1. Analysis of dates from architecture.

DATES FROM ARCHITECTURE

UCLA-1676A	Patallacta, dep. Cuzco, Peru.
365±60 BP	The sample derived from window lintel of Inca structure. After calibration we obtained two peaks - 1500 AD and 1610 AD with equal probability. Lack of colonial material indicates rather Inca Imperial Phase than colonial period (Kendall, 1976; Ziółkowski et al., 1994).
UCLA-1676B	Tunasmocco, dep. Cuzco, Peru.
415±60 BP	The sample derived from window lintel of Inca structure. After calibration we obtained two peaks - 1450 AD and 1610 AD. The first peak is more probable and seems to be relevant with archaeological context (Inca structure, lack of colonial material) (Kendall, 1976; Ziółkowski et al., 1994).
UCLA-1676D	Canamarca, dep. Cuzco, Peru.
475±60 BP	The sample was collected from trapezoidal niche. After calibration we obtained three peaks: 1325 AD, 1440 AD and 1610 AD. Only the second peak is important, what is in accordance with archaeological context (characteristic for Imperial Phase, trapezoidal niche; lack of colonial material) (Kendall, 1976; Ziółkowski et al., 1994).
UCLA-1676K	Yucay, dep. Cuzco, Peru.
365±60 BP	The sample was collected from window lintel if Inca structure. After calibration we obtained two peaks: 1500 AD and 1610 AD with equal probability. Lack of colonial material suggest Inca Imperial Phase (Kendall, 1976; Ziółkowski et al., 1994).
UCLA-1676M	Ancasmarca, dep. Cuzco, Peru.
660±60 BP	The sample was collected from unknown archaeological context. After calibration we obtained two peaks - 1300 AD and 1375 AD - indicating Preimperial Phase (Kendall, 1976; Ziółkowski et al., 1994).
BM-924	Choquepuquio, dep. Cuzco, Peru.
695±59 BP	The sample was collected from wooden girder of the wall. Lucre and Killke ceramic was found in the same layer. After calibration we obtained two peaks - with max. at 1300 AD and 1375 AD - both in accordance with archaeological context (Kendall, 1976; Burleigh et al., 1977; Ziółkowski et al., 1994).
BM-925	Canaraccay, dep. Cuzco, Peru.
425±67 BP	The sample was collected from niche lintel made of plaiting cane. After calibration we obtained two peaks: 1475 AD and 1610 AD. The first peak is statistically more significant than the second one and seems to be relevant to archaeological context (there is not information about existence of any colonial material) (Kendall, 1976; Burleigh et al., 1977; Ziółkowski et al., 1994).

BM-929 Urco, dep. Cuzco, Peru.

307±41 BP The sample derived from niche at the building on the rock. After calibration we obtained two peaks: 1530 AD and 1650 AD. Lack of information about existence of colonial material indicates rather Inca Imperial Phase than colonial period (Kendall, 1976; Burleigh et al., 1977; Ziółkowski et al., 1994).

BM-930 Ancasmarca, dep. Cuzco, Peru.

482±91 The sample was collected from unknown archaeological context. After calibration we obtained three peaks - 1325 AD, 1440 AD (the most probable) and 1610 AD (Kendall, 1976; Burleigh et al., 1977; Ziółkowski et al., 1994).

SI-6987 Pumamarca, dep. Cuzco, Peru.

710±50 BP The sample was collected from wooden lintel of the door. After calibration we obtained two almost separated, equally probable peaks with max. ca 1275 AD and 1375 AD. In A.Kendall opinion this structure belongs to Preinca Phase (Hollowell, personal communication).

SI-6988A Pumamarca, dep. Cuzco, Peru.

660±50 BP The sample derived from wooden lintel. After calibration we obtained two peaks - 1300 AD and 1375 AD with similar probability, both indicating Preimperial Phase (Hollowell, personal communication).

SI-6988B Pumamarca, dep. Cuzco, Peru.

645±45 BP The sample derived from burned house constructed in the Pirca technique. After calibration we obtained two peaks - narrower peak with max. at ca 1300 AD and wider one with max. at ca 1375 AD - both indicating Preimperial Phase (Hollowell, personal communication).

SI-6990 Kachiquata, dep. Cuzco, Peru.

640±55 BP The sample was collected from wooden lintel of building constructed in the Pirca technique. This house is situated near the quarry from which the material used in construction of Ollantaytambo was extracted. According to explorer (J.L.Hollowell) this building could have been a guardian house. After calibration we obtained two peaks: first peak at ca 1310 AD and second - more wider one - at ca 1360-1380 AD. Lack of more detailed archaeological context (including artefacts) does not permit to declare definitively, which phase the sample belong to (Hollowell, personal communication).

SI-6989 Intihuatana, dep. Cuzco, Peru.

515±50 BP The sample derived from wooden lintel of house, which was constructed in the Pirca technique. In accordance with the opinion of J.L.Hollowell, this structure may be assigned to Pachakuti Inca Yupanqui period. After calibration we obtained two peaks: 1325 AD and 1425 AD. The last one is more probable (Hollowell, personal communication).

WIS-1939 Cerro Azul, dep. Lima, Peru.

480±60 BP The sample derived from mud-walled compound. In accordance with the archaeological comment, that this site was abandoned following Inca conquest. After calibration we obtained three peaks - 1325 AD, 1440 AD and 1610 AD. The second peak is significantly more probable than the other ones (Marcus, 1987; Steventon, Kutzball, 1985; Ziółkowski et al., 1994) .

SI-6991A Ollantaytambo, dep. Cuzco, Peru.

470±70 BP The sample was collected from wooden lintel of window. The house was built in the Pirca technique. After calibration we obtained three peaks - ca. 1340 AD, 1440 AD and 1610 AD. The second peak is significantly more probable than the other ones (Hollowell, personal communication).

Gx-6833 Farfan, dep. La Libertad, Peru.

535±125 BP The sample derived from store-house, called *audiencia* - the structure characteristic for Chimu culture. The archaeological comment indicates Inca-Chimu period. After calibration we obtained two significant peaks with max. at 1350 AD and 1425 AD. The second peak is more probable. It might indicate the early Imperial Phase, but it may be also a result of commercial contacts with the Incas, before their expansion. This date was calibrated with 2σ calibration range (Keatinge, Conrad, 1983, Ziółkowski et al., 1994).

Gx-6829	Farfan, dep. La Libertad, Peru.
450±120 BP	The sample derived from wooden post found in adobe wall. This site was occupied in Imperial-Chimu and Chimu-Inca periods. After calibration we obtained three peaks at 1325 AD, 1440 AD and 1625 AD. The second and third peaks have similar probability, whereas the first one is significantly less probable. Therefore the second peak seems to be relevant to the context, however lack of information about existence of cultural markers (e.g. Chimu, Inca or colonial ceramic) does not permit to solve this problem definitively. This date was calibrated with 2σ calibration range (Keatinge, Conrad, 1983, Ziółkowski et al., 1994).
SI-6991B	Ollantaytambo, dep. Cuzco, Peru.
390±100 BP	The sample was collected from a hearth situated in Fortress in association with non-Inca brown ceramic. After calibration we obtained two peaks: 1475 AD and 1610 AD with equal probability. This date was calibrated with 2σ calibration range(Hollowell, personal communication)..
ISGS-545	Qata Casallacta, dep. Cuzco, Peru.
370±80 BP	The sample derived from layer connected with the floor of Inca structure. After calibration we obtained two peaks at ca 1500 AD and 1610 AD with equal probability. Lack of colonial material indicates rather Inca Imperial Phase than colonial period. This date was calibrated with 2σ calibration range (Li Liu et al., 1986; Ziółkowski et al., 1994).
Beta-22437	San Antonio, dep. Moquegua, Peru.
370±60 BP	The sample was collected from Structure 20 in association with Inca pottery. After calibration we obtained two peaks - 1500 AD and 1600 AD with equal probability. This date was calibrated with 2σ calibration range (Stanish, Rice, 1989; Conrad, Webster, 1989; Ziółkowski et al., 1994).
BM-931	Ollantaytambo, dep. Cuzco, Peru.
294±54	The sample derived from window lintel of Inca building. After calibration we obtained two peaks - at ca 1530 AD and ca 1650 AD. The first peak seems to be in accordance with archaeological context (lack of colonial material, information that the sample comes from Inca house - Inca Imperial Phase). This date was calibrated with 2σ calibration range(Kendall, 1976; Burleigh et al., 1977; Ziółkowski et al., 1994).

TABLE 2. Analysis of dates from artefacts.

DATES FROM ARTEFACTS

I-1479	Chilca, dep. Lima, Peru.
700±120 BP	The sample derived from layer, which Inca ceramic was found in together with Post-Tiahuanaco textiles (Tambo II). After calibration we obtained two wide peaks at 1280 AD and 1370 AD (Ravines, Alvarez Sauri, 1967; Ravines,1982; Ziółkowski et al., 1994).
Gak-108	Churajon, dep. Arequipa, Peru.
554±70 BP	The sample was collected from unknown archaeological context. This site was occupied during Inca Period. After calibration we obtained two peaks at ca. 1325 AD and 1410 AD. The second peak is statistically more probable (Ravines, Alvarez Sauri, 1967; Ravines,1982; Ziółkowski et al., 1994).
MC-2352	Patamarca, dep. Junin, Peru.
480±70 BP	The sample derived from level with Inca pottery. After calibration we obtained three peaks with max. at ca. 1325 D, 1430 AD and 1610 AD. The second peak is statistically the most significant (the third is negligible), what is in accordance with archaeological comment (presence of Inca ceramic, lack of colonial material) (Bonnier, Rozenberg, 1982; Ziółkowski et al., 1994).
Tk-193	La Pampa, dep. Ancash, Peru.
500±70 BP	The sample was collected from the inside of arrybalus in Inca Local style. After calibration we obtained three peaks: 1325 AD, 1435 AD and 1610 AD (Kobayash et al., 1974; Ziółkowski et al., 1994).
KN-2622	Quebrada de Moca, dep. Arequipa, Peru.
350±50 BP	The sample was collected from passage between two houses, not far from the Inca road. After calibration we obtained two peaks - 1500 AD and 1625 AD (Trimborn, 1988; Ziółkowski et al., 1994).

Tk-93 Ancash, dep. Lima, Peru.

530±80 BP The sample was collected from textiles and gourd debris, found in a tomb. According to investigator's comment main grave pertained to Inca culture. After calibration we obtained three peaks: 1340 AD, 1412 AD and 1620 AD. The second peak is the most probable and refers to archaeological context (Inca grave, lack of colonial material) (Kobayash et al., 1974; Ziółkowski et al., 1994).

P-1846 Quebrada Honda, dep. Arequipa, Peru.

630±40 BP The sample was collected from level with Inca ceramic, however not far from this site Nazca terraces were found. The probability distribution of calibrated age has two peaks - at ca. 1310 AD, 1350 AD and 1380 AD. It seems that this date comes from mixed context, but theoretically it could be a result of early contact with Inca State (Ravines, Alvarez Sauri, 1967; Ravines,1982; Lawn, 1974; Ziółkowski et al., 1994).

L-123b Pachacamac, dep. Lima, Peru.

900±150 BP The sample was collected from rubbish in association with Inca ceramic, situated out of the Templo del Sol. The probability distribution obtained as a result of calibration is very flat, what is a consequence of small precision of the date (50% confidence interval of this date: 1038-1213 AD). Additionally the archaeological context is unclear, so it is possible that the sample derived from layer with mixed material or the rubbish could be utilised during long period. Concluding, this date indicates rather Preimperial than Imperial Phase (Ravines, Alvarez Sauri, 1967; Ravines,1982; Ziółkowski et al., 1994).

UGa-4661 Santa Barbara, dep. Cajamarca, Peru.

395±75 BP The sample was collected from unknown archaeological context but there were storehouse - qolqa in this state. After calibration we obtained two peaks at ca. 1460 AD and 1610 AD with equal probability. Lack of colonial material and presence of typical for Inca Imperial Phase storehouse (qolqa) would indicate the first peak (Chiswell, 1986; Ziółkowski et al., 1994).

UGa-4662 Santa Barbara, dep. Cajamarca, Peru.

475±65 BP The sample derived from site with store-house system, called colqa. After calibration we obtained three peaks , but only the second peak - 1440 AD is statistically important (Chiswell, 1986; Ziółkowski et al., 1994).

WIS-1936 Cerro Azul, dep. Lima, Peru.

420±70 BP The sample was collected from a pit with maize. The site was abandoned following Inca conquest during Pachakuti Inca Yupanqui reign. After calibration we obtained two peaks: 1460 AD and 1610 AD with equal probability. The site description would indicate the first peak, because there is any evidence of presence of colonial material (Marcus, 1987; Steventon, Kutzball, 1985; Ziółkowski et al., 1994) .

UCLA-2538E Machu Picchu, dep. Cuzco, Peru.

380±40 BP The sample derive from Citadel ruins (61-70 cm level) where Inca Imperial ceramic were found. After calibration we obtained two peaks - 1470 AD and 1610 AD (Berger et al., 1988; Ziółkowski et al., 1994).

UCLA-2538A Machu Picchu, dep. Cuzco, Peru.

595±105 BP The sample was collected from Citadel ruins. According to the historical sources this structure was built during Pachakuti Inca Yupanqui and Top Inca Yupanqui reign. After calibration we obtained two peaks: 1325 AD and 1400 AD (Berger et al., 1988; Ziółkowski et al., 1994).

UCLA-2538F Machu Picchu, dep. Cuzco, Peru.

390±40 BP The sample derive from Citadel ruins (61-70 cm level) where Inca Imperial ceramic were found. After calibration we obtained two peaks - 1470 AD and 1610 AD (Berger et al., 1988; Ziółkowski et al., 1994).

UCTL-281 Cerro Grande Compania, Chile.

510±60 BP The sample derived from Inca Fortress, where Inca Imperial and Inca Local ceramic were found. After calibration we obtained peaks at ca. 1330 AD and 1430 AD. The second peak i statistically more significant (Dillehay, 1992).

UCTL-229 Cerro Grande, de la Compania, Chile.

460±45 BP The sample was collected from Inca fortress, where Inca Cuzco and Inca Local ceramic were found. After calibration we obtained two peaks - 1440 AD and 1610 AD, but the second peak is statistically unimportant (Dillehay, 1992).

CSIC-322	Inga Pirca, prov. Canar, Ecuador.
690±80 BP	The sample was collected from house F in association with Inca pottery, but there was mixed material in this layer. After calibration we obtained two peaks - 1300 AD and 1370 AD (Ravines, Alvarez Sauri, 1967; Ravines,1982; Fresco, 1984; Alcina, Franch, 1981; Ziółkowski et al., 1994).
CSIC-335	Inga Pirca, prov. Canar, Ecuador.
550±60 BP	The sample was collected from area near the Inca building. From archaeological comment appear that Inca pottery mixed with local one were found on surface. After calibration we obtained two peaks - 1325 AD and 1410 AD (Ravines, Alvarez Sauri, 1967; Ravines,1982; Fresco, 1984; Alcina, Franch, 1981; Ziółkowski et al., 1994).
Tx-2006	Huancayo Alto, dep. Lima, Peru.
580±100 BP	The sample derived from unknown archaeological context, but Inca architecture and ceramic occurred in this site. After calibration we obtained two peaks - 1325 AD and 1400 AD with equal probability (Vlastro et al., 1978; Ziółkowski et al., 1994).
Hv-350	Cancay, dep. Lima, Peru.
740±50 BP	The sample was collected from Inca mummy bundle. After calibration we obtained two peaks: 1280 AD and 1375 AD. The first peak is statistically more significant (Geyh, Schneekloth, 1964; Ziółkowski et al., 1994).
WIS-1937	Cerro Azul, dep. Lima, Peru.
520±70 BP	The sample derived from pile of corn-cob, which was left when building was abandoned following Inca conquest. After calibration we obtained two peaks - 1330 AD and 1420 AD. The second peak is more probable (Marcus, 1987; Steventon, Kutzball, 1985; Ziółkowski et al., 1994) .
L-123C	Pachacamac, dep. Lima, Peru.
500±120 BP	The sample was collected from llama skin. The Inca ceramic was found in the same layer. After calibration we obtained three peaks: 1325 AD , 1425 AD and 1610 AD. This date was calibrated with 2σ calibration range (Ravines, Alvarez Sauri, 1967; Ravines,1982; Ziółkowski et al., 1994).
I-1482	La Centinela, dep. Lima, Peru.
485±70 BP	The sample derived from level with Inca-Cuzco ceramic. After calibration we obtained three peaks - 1325 AD, 1440 Ad and 1610 AD. This date was calibrated with 2σ calibration range (Engel, 1966; Ziółkowski et al., 1994).
I-1476	Rupashca Wasi, dep. Lima, Peru.
400±100 BP	The sample was collected from layer with Inca and Local brown ceramic. After calibration we obtained two peaks - 1450 AD and 1610 AD with equal probability. This date was calibrated with 2σ calibration range (Ravines, Alvarez Sauri, 1967; Ravines,1982; Ziółkowski et al., 1994).
AC-0331	Cerro Mercedario, prov. San Juan, Argentina.
350±50 BP	The sample derived from partially burned wood collected from a room, where Inca ceramic were found. This date was calibrated with 2σ calibration range (Alberto, Angiolini, 1985).
HAM-621	Quebrada de la Vaca, dep. Arequipa, Peru.
300±80 BP	The sample was collected from storehouse - qolqa (No 7). The probability distribution obtained in consequence of calibration is very flat and gives the same value of probability for interval 1450-1650 AD. This date was calibrated with 2σ calibration range (Trimborn, 1988; Ziółkowski et al., 1994).

Results

The main aim of our work was to assign length of the Inca Preimperial and Imperial Phase, as well as length of periods of succeeding Inca rulers reign, using calibrated radiocarbon dates. The shape of calibration curve concerning XIII-XVI century (Fig.1) is satisfactory to try to make considerations on the Inca State chronology.

Figure 4 (the narrowest 95% confidence intervals of the dates included to analysis) shows a visible division of radiocarbon dates on two groups. The limit between them is ca. 1450 AD, what is in accordance with historical sources, which locates the beginnings of the Inca Imperial phase in 1438 AD. Nevertheless, the analysis of particular calibrated radiocarbon dates did not give expected results, because of their low accuracy (Adamska, 1991). Therefore we decided to apply a composite probability distribution - very useful tool for such type of analysis. Composite probability distribution is obtained simply by summarising on probability distribution of calendar age of samples, which belongs to the analysed phase or culture. The likelihood distribution constructed this way gives us information about a limits of investigated period.

TABLE 3. List of radiocarbon dates representing Inca Imperial Phase and Inca Preimperial Phase included to analysis.

IMPERIAL PHASE		
No. Sample name	lab. code	C-14 age conv. y BP
1 Patayacta Urubamba	UCLA-1676a	365±60
2 Tunasmocco	UCLA-1676b	415±60
3 Canamarca	UCLA-1676d	475±60
4 Yucay	UCLA-1676k	365±60
5 Canaracay	BM-925	425±67
6 Urco J	BM-929	307±41
7 Ancas Marca	BM -930	482±91
8 Patamarca	MC-2852	480±70
9 La Pampa	TK-198	500±70
10 Quebrada de Moca	KN-2622	350±50
11 Ollantaytambo	SI-6991A	470±70
12 Ancon	TK-93	530±80
13 Cerro Santa Barbara	UGa-4661	395±75
14 Cerro Santa Barbara	UGa-4662	475±65
15 Cerro Azul	WIS-1936	420±70
16 Cerro Azul	WIS-1939	480±60
17 Machu Picchu	UCLA-2538e	380±40
18 Machu Picchu	UCLA-2538a	595±105
19 Machu Picchu	UCLA-2538f	390±40
20 Cerro Grande	UCTL-281	510±60
21 Cerro Grande	UCTL-229	460±45
22 Huancayo Alto	TX-2006	580±100
23 Batan Grande	Beta-2591	450±60
24 Cerro Azul	WIS-1987	520±70

PREIMPERIAL PHASE		
No. Sample name	lab. code	C-14 age conv. y BP
1 Ancas Marca	UCLA-1676m	660±60
2 Choquepuquio	BM-924	695±59
3 Chilca	I-1479	700±120
4 Quebrada Honda	P-1846	630±40
5 Pumamarca	SI-6987	710±55
6 Pumamarca	SI-6988a	660±50
7 Pumamarca	SI-6988b	645±45
8 Kachiqhata	SI-6990	640±50
9 Inithuatana	SI-6989	515±50
10 Pacachamac	L-123b	900±150
11 Chancay	Hv-350	740±50

First, we wanted to estimate the time-limits of Preimperial Phase and Imperial Phase - consequently we created two groups of dates. The first group contains dates from samples collected from archaeological context, which can be recognised as Inca Imperial Phase. The dates from samples, which assumable represent Inca Preimperial Phase are included into the

second group. We made efforts to assign each date to appropriate group in accordance with archaeological information. Unfortunately a few dates was obtained from samples coming from archaeological context defined not enough well and we decided to include these samples to one of our groups basing on its radiocarbon age. The list of dates included to each group is presented in Table 3

Moreover we attempted to make rough estimate of the time-intervals corresponding to periods, when succeeding rulers of the Inca Empire had been in authority. Because there do not exist any simple markers, which could indicate each of rulers, we reached a decision, that all dates from territories incorporated by succeeding Incas would be included to one group. Therefore we created four groups of dates listed in Table 4.

The dates from all groups were calibrated using the Gliwice Calibration Program GdCALIB ver.6.0 (Pazdur & Michczyńska 1989). The calibration curves used for the calculation were taken from "Radiocarbon" - "Calibration 1993" (Stuiver, Long and Kra, 1993). We calibrated dates without correction for systematic age difference between northern and southern hemisphere.[2] Furthermore all dates were calibrated with analysed interval $\pm 3\sigma$ wide.

TABLE 4. List of radiocarbon dates obtained from territories incorporated by succeeding rulers of The Inca Empire.

No. Sample name	lab. code	C-14 age conv. y BP
GROUP A: DATES FROM CUZCO REGION AND TERRITORIES INCORPORATED BY INCA PACHACUTI		
1 Machu Picchu	UCLA-2538e	380±40
2 Machu Picchu	UCLA-2538a	595±105
3 Machu Picchu	UCLA-2538f	390±40
4 Huancayo Alto	TX-2006	580±100
5 Chancay	Hv-350	740±50
6 Patayacta Urubamba	UCLA-1676a	365±60
7 Tunasmocco	UCLA-1676b	415±60
8 Canamarca	UCLA-1676d	475±60
9 Yucay	UCLA-1676k	365±60
10 Ancas Marca	UCLA-1676m	660±60
11 Choquepuquio	BM-924	695±59
12 Canaracay	BM-925	425±67
13 Urco J	BM-929	307±41
14 Ancas Marca	BM -930	482±91
15 Ollantaytambo	SI-6991A	470±70
16 Pumamarca	SI-6987	710±55
17 Pumamarca	SI-6988a	660±50
18 Pumamarca	SI-6988b	645±45
19 Kachiqhata	SI-6990	640±50
20 Inithuatana	SI-6989	515±50
21 Patamarca	MC-2351	480±70

No. Sample name	lab. code	C-14 age conv. y BP
GROUP B: DATES FROM TERRITORIES INCORPORATED BY TOPA INCA DURING REIGN INCA PACHACUTI		
1 Pacachamac	L-123b	900±150
2 Cerro Santa Barbara	UGa-4661	395±75
3 Cerro Santa Barbara	UGa-4662	475±65
4 Batan Grande	Beta-2591	450±60
5 Chilca	I-1479	700±120
6 Ancon	TK-93	530±80
7 La Pampa	TK-193	500±70
GROUP C: DATES FROM TERRITORIES INCORPORTED BY TOPA INCA		
1 Cerro Azul	WIS-1936	420±70
2 Cerro Azul	WIS-1939	480±60
3 Cerro Grande	UCTL-281	510±60
4 Cerro Grande	UCTL-229	460±45
5 Cerro Azul	WIS-1987	520±70
6 Churajon	GaK-108	554±70
7 Quebrada de Moca	KN-2622	350±50
8 Quebrada Honda	P-1846	630±40
GROUP D: DATES FROM TERRITORIES INCORPORATED BY HUAYNA CAPAC		
1 Inga Pirca	CSIC-322	690±80
2 Inga Pirca	CSIC-335	550±60

[2]The composite probability distributions obtained by calibration with this correction do not differ considerable from the distributions presented in this paper, so all conclusions would leave unchanged even though the calculation are carried out with the correction. Limits of confidence intervals presented in Table 5 and Table 6 would be shifted in this instance from ca 5 to ca 25 years in the direction of younger dates.

The composite probability distributions of calibrated radiocarbon dates for Preimperial and Imperial Phase, obtained as results of calibration of groups presented in Table 3, are shown in Figure 5. The distribution for Preimperial Phase has a shape with highest part between approx. 1275-1425 AD. This part has distinct, steep edges. Two peaks on the top of distribution are caused most likely by the fact, that the calibration curve has wiggles for values of calendar age from interval ca. 1300-1400 AD (the calibration curve is broken up and down there). It is not straightforward task to decide, which parameters or features of distribution would give the best information about real time-limits of analysed phase. Table 5 shows confidence intervals we consider, that may give good image of reality. There are 68% confidence interval (corresponds with $\pm 1\sigma$ interval of radiocarbon date), 50% confidence interval, which conforms to conception of the *floruit* of culture (Ottaway, 1973; Aitchison *et al.*, 1991) and the narrowest 68% confidence interval. The last one gives us intervals of the highest values of probability, which corresponds with $\pm 1\sigma$ interval of radiocarbon date. After analysis of probability distribution, we may assume, however, that the edges of the highest part correspond very well with limits of Preimperial Phase. Therefore, the best estimation of these limits would be the narrowest 68% confidence interval. We should lay emphasis on good agreement between all intervals for Inca Preimperial Phase presented in Table 5.

TABLE 5. Confidence intervals for composite probability distributions obtained as result of calibration of dates representing Inca Imperial Phase and Inca Preimperial Phase. The narrowest 68% confidence interval for Inca Imperial Phase is divided into two parts. In brackets the probability of each part of interval is placed.

	50% confidence interval [calendar years AD]	68% confidence interval [calendar years AD]	68% confidence interval (narrowest) [calendar years AD]
Inca Preimperial Phase	1288 - 1373	1262 - 1387	**1280 - 1396**
Inca Imperial Phase	1425 - 1552	1406 - 1590	**1401 - 1518** (54%) 1578 - 1624 (14%)

Interpretation of cumulative probability distribution obtained for dates representing Inca Imperial Phase is more sophisticated. The distribution has three, almost separated peaks with maxima at ca 1325 AD, 1450 AD and 1600 AD, where the second (central) peak is statistically the most important (Fig.5). This complicated shape of probability distribution is caused by a wiggles of calibration curve, which occur for values of calendar years 1300-1400 AD and 1475-1650 AD (see Fig.1). Therefore, we have here an example of the same problem as we described above (Figure 2) - we can assume that we found three possible locations of interval representing Inca Imperial Phase. But we know from reliable historical sources, that the last bastion of the Inca State - Vilcabamba - fell in 1572, so the third peak (ca 1600 AD) falls in colonial period and it can not conform to Inca Imperial Phase. Basing on these irrefutable facts we may remove the third peak from the area our interest. Because the first peak falls rather in Preimperial Phase (and its importance is a little), we may expect, that only the second (central) peak corresponds with Imperial Phase. Consequently an edges of this peak may be assumed as conforming to limits of Inca Imperial Phase.

TABLE 6. Confidence intervals for composite probability distributions obtained as result of calibration of groups presented in Table 4. The narrowest 68% confidence intervals are divided into two or three parts. In brackets the probability of each part of interval is placed.

	50% confidence interval [calendar years AD]	68% confidence interval [calendar years AD]	68% confidence interval (narrowest) [calendar years AD]
GROUP A	1345 - 1513	1313 - 1569	1283 - 1498 (66%) 1604 - 1613 (2%)
GROUP B	1325 - 1478	1247 - 1523	1306 - 1364 (11%) 1375 - 1518 (49%) 1579 - 1624 (8%)
GROUP C	1390 - 1484	1352 - 1537	1308 - 1358 (15%) 1381 - 1485 (53%)

Table 5 shows 50% confidence interval, 68% confidence interval and the narrowest 68% confidence interval for discussed likelihood distribution. However these intervals apply to whole distribution, whereas the central peak only gives us interesting information. 50% and 68% confidence intervals are therefore inadequate to our purpose. But we may quite well estimate the limits of Inca Imperial Phase using this part of the narrowest 68% confidence interval, which refer to the second peak i.e. 1401-1518 AD.

Figure 6 shows the composite probability distributions obtained as results of calibration of groups presented in Table 4. Group D was excluded from analysis, because it was composed of two, probably aberrant dates only. Table 6 presents 50% confidence interval, 68% confidence interval and the narrowest 68% confidence interval for these distributions. Unfortunately, we are not able to distinguish, basing on obtained distributions, between periods of succeeding Inca reign. It is mainly due to too small accuracy of radiocarbon dates included to analysis.

Final remarks

We would like to lay emphasis on fact, that our paper is the first attempt to establish of the Inca state chronology basing on complex analysis of radiocarbon dates, therefore the limits of periods we obtained do not claim to be decisive. Particularly the systematic age difference between northern and southern hemisphere is one of a reasons for doubts. As we mentioned above the analysis taking into account the correction for age difference gives intervals presented in Table 5 and 6 shifted about 20-25 years. Therefore we have to assume, that the limits of periods are definite with accuracy ca 20 years. The intervals obtained with the correction are even in better accordance with historical sources than intervals calculated without the correction. Moreover we realise, that increase of quantity of radiocarbon dates related to well-defined archaeological context and included to the analysis would make the results more reliable. For all that we are of opinion, that from presented results we may draw following conclusions:

– The obtained limits of Inca Imperial Phase seem to confirm limits, which were based on historical sources (the chronicles).
– Inca Preimperial Phase seems to be by our estimation about 120-150 years long.

Results described above clearly show, that the analysis of calibrated radiocarbon dates may be an useful tool for investigation of controversial problems relating to Inca state chronology.

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APPENDIX 1 - The list of the Kings (by Miguel Cabello de Valboa).

1.	Manco Capac	945-1006 AD
2.	Sinchi Roca	1006-1083 AD
3.	Lloque Yupanqui	1083-1161 AD
4.	Maita Capac	1161-1226 AD
5.	Capac Yupanqui	1226-1306 AD
6.	Inca Roca	1306-1356 AD
7.	Yahuar Huacac	1356-1386 AD
8.	Viracocha Inca	1386-1438 AD
9.	Pachacuti Inca Yupanqui	1438-1471 AD
10.	Topa Inca Yupanqui	1471-1493 AD
11.	Huayna Capac	1493-1528 AD
12.	Huascar Inca	1528-1532 AD
13.	Atahuallpa	1532-1533 AD
14.	Manco Inca	1533-1545 AD

APPENDIX 2 - A Chronological Models

1st MODEL - MONARCHY	2nd MODEL - DIARCHY	
	The Hanan Cuzco Dynasty	The Hurin Cuzco Dynasty
Manco Capac	Manco Capac	
Sinchi Roca	Inca Roca	Sinchi Roca
Lloque Yupanqui	Yahuar Huacac	Lloque Yupanqui
Maita Capac	Viracocha Inca	Maita Capac
Capac Yupanqui	Pachacuti Inca Yupanqui	Capac Yupanqui
Inca Roca	Topa Inca Yupanqui	
Yahuar Huacac	Huayna Capac	
Viracocha Inca	Huascar Inca	
Pachacuti Inca Yupanqui	Atahuallpa	
Topa Inca Yupanqui		
Huayna Capac		
Huascar Inca		
Atahuallpa		
Manco Inca		

Fig. 1. Fragment of calibration curve for calendar years 1000-1950 AD

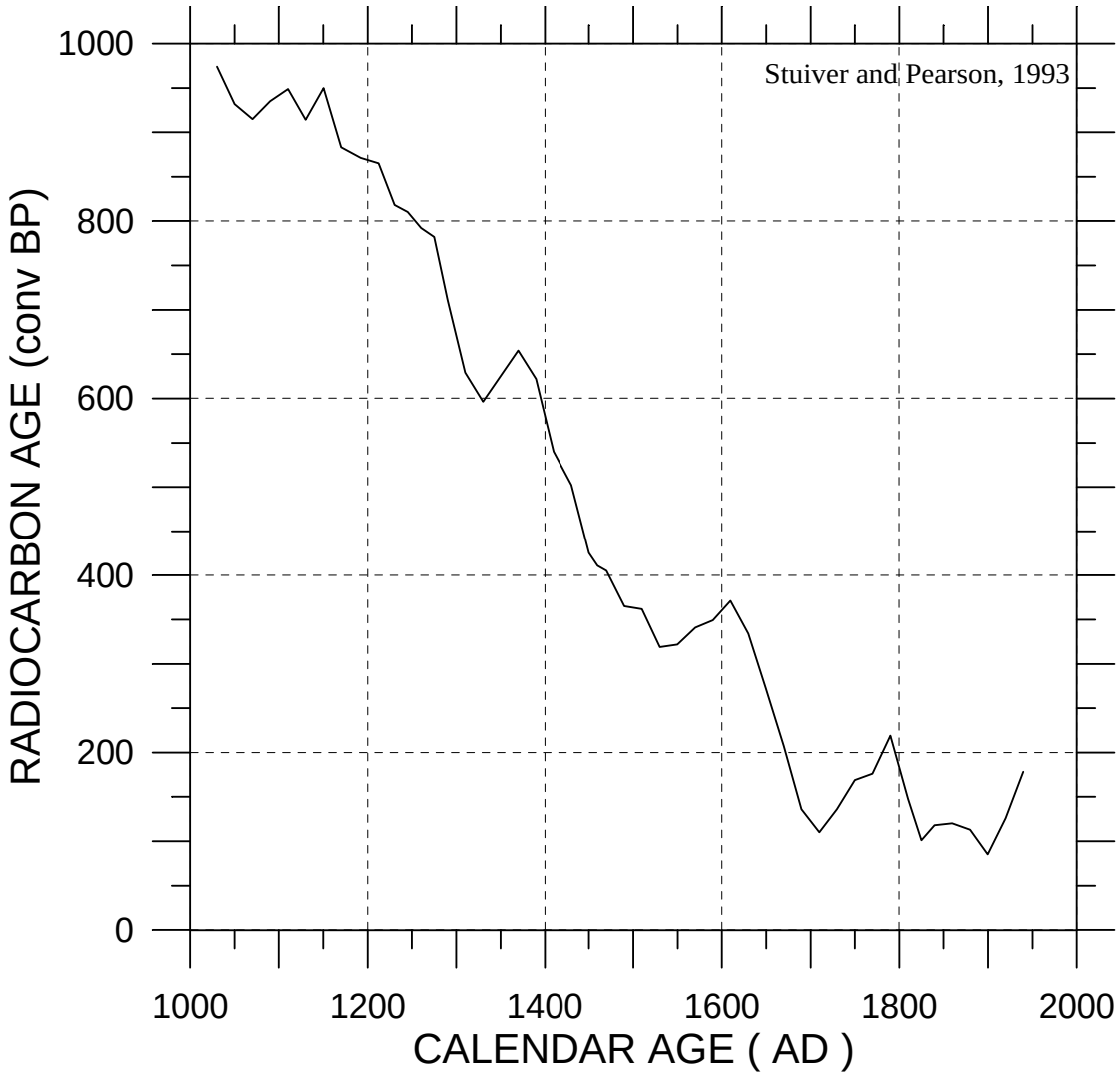

Fig.2. An example of probabilistic calibration of radiocarbon date SI-6987 (710±55 BP). The final probability distribution of calendar age has two separated peaks (modes).

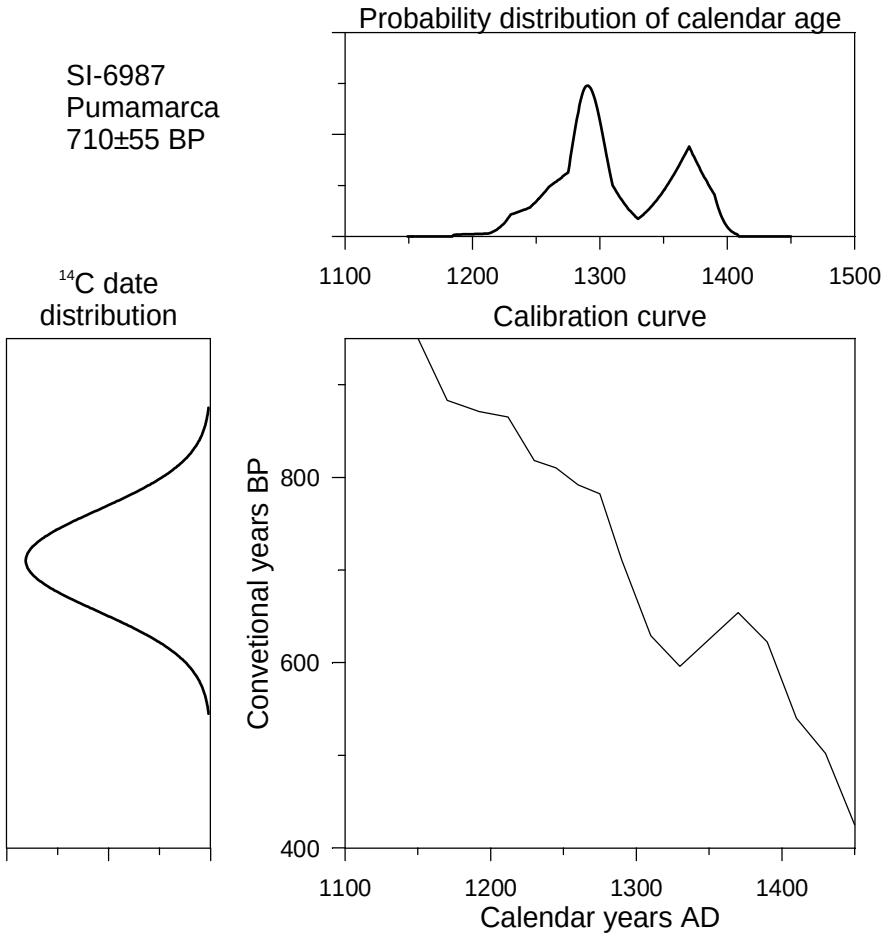

Fig.3. Probability distributions of radiocarbon dates including to analysis. Distributions presented with dark colour were calibrated with analysed interval ±3σ, distributions presented with fair colour were calibrated with analysed interval ±2σ.

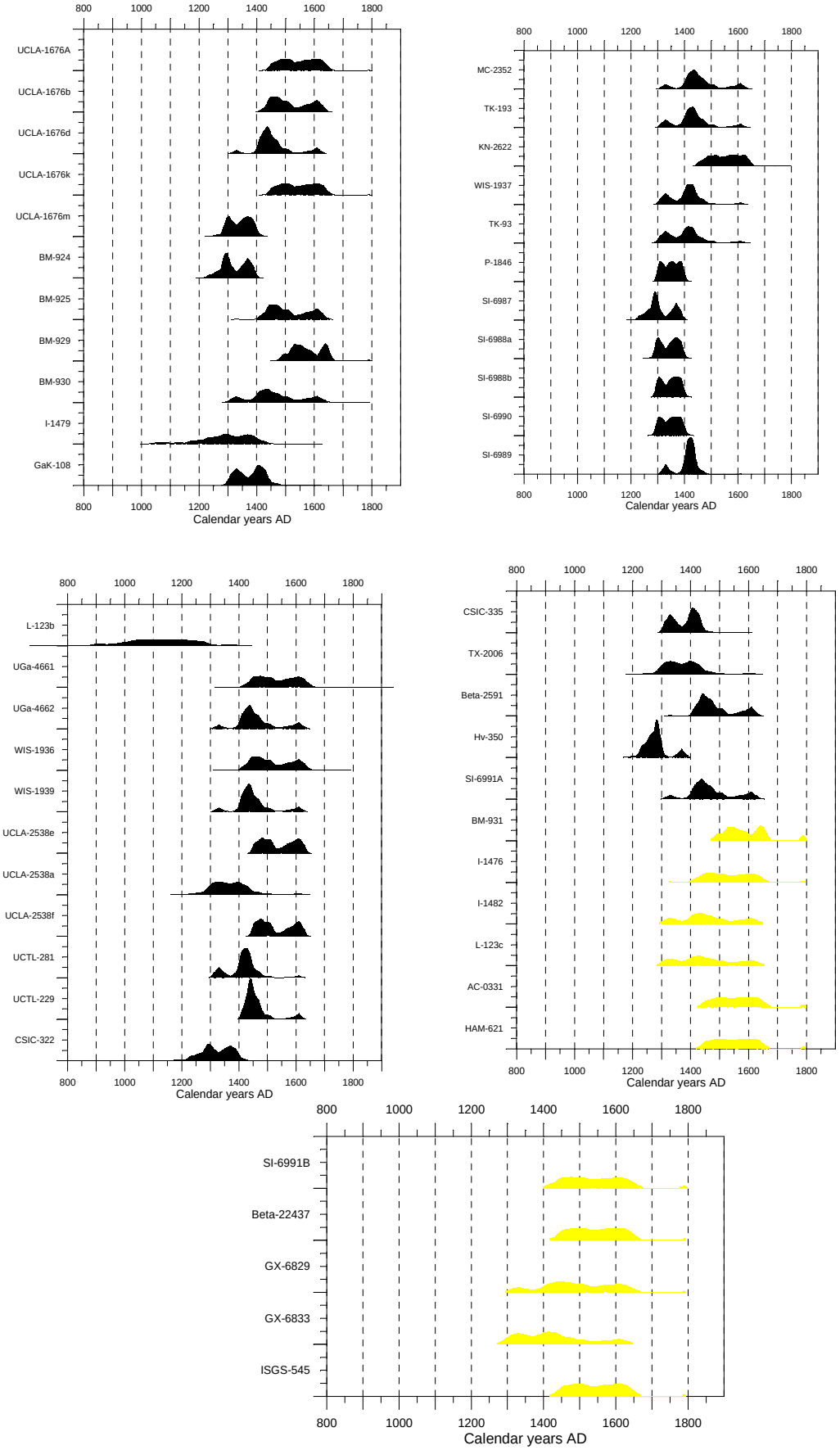

Fig.4. The narrowest 95% confidence intervals of the dates inculuded to analysis. Vertical permanent lines show a limits of Inca Imperial phase established basing on histarical sources.

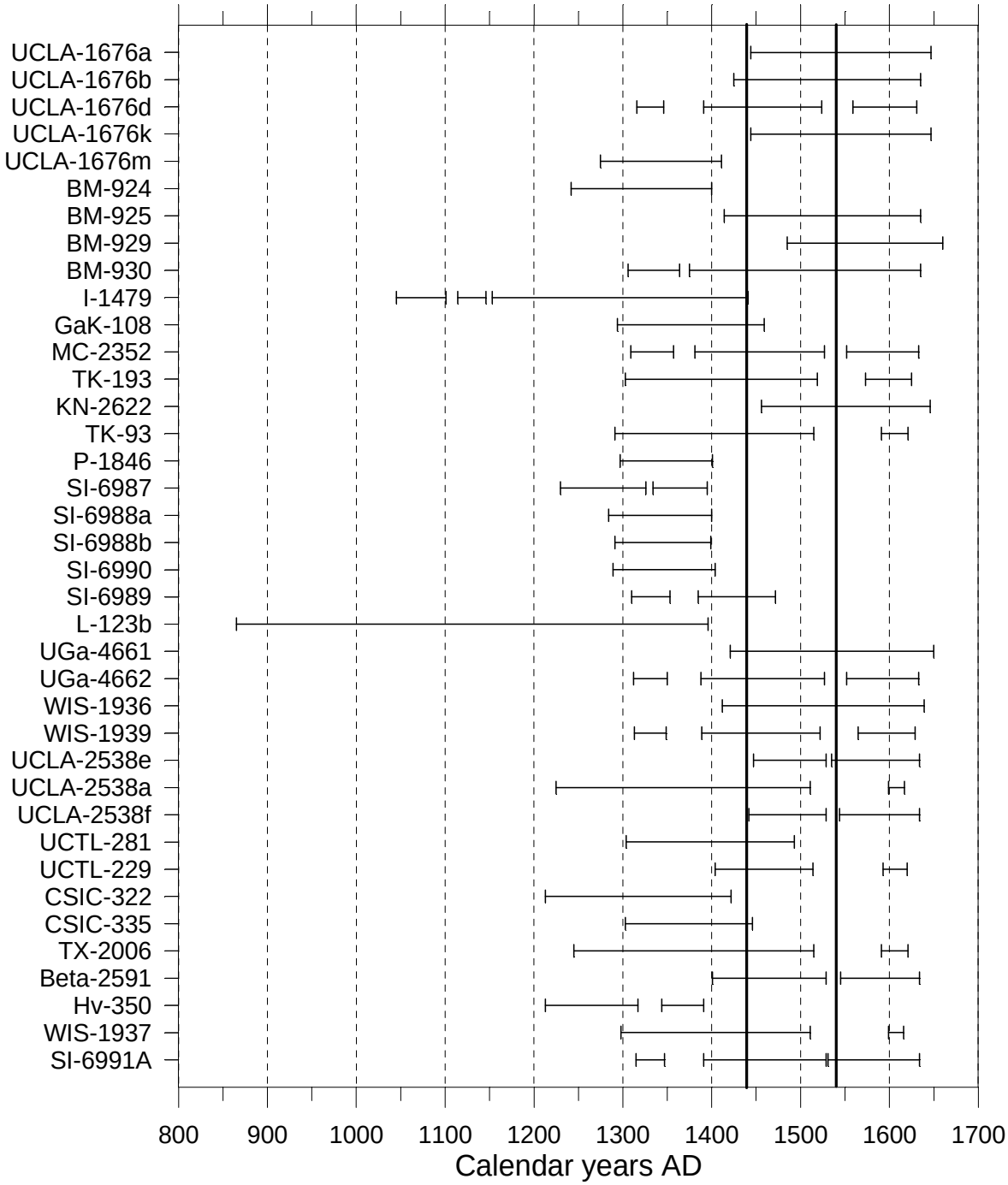

Fig.5. Composite probability distributions of calibrated radiocarbon dates for Inca Preimperial and Inca Imperial Phase. Thin, vertical lines show limits of phases estimated basing on the narrowest 68% confidence intervals (see text).

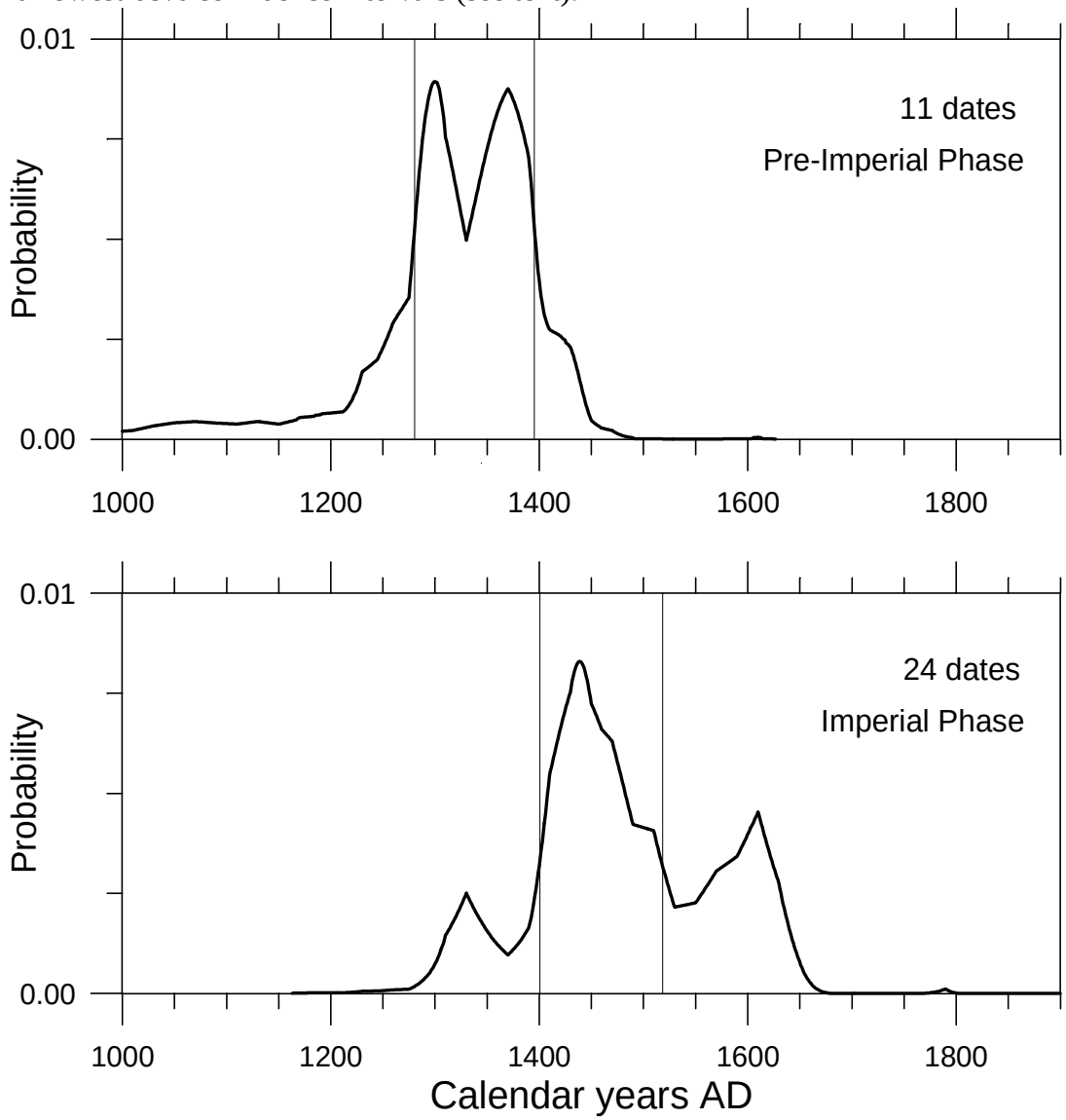

Fig.6. Composite probability distribution of calibrated radiocarbon dates from territories incorporated during succeeding rulers of the Inca Empire reign.