DENDROCHRONOLOGICAL INVESTIGATIONS AT PORSUK/ULUKIŞLA, TURKEY PRELIMINARY REPORT, 1987-1989

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On 14, 15, and 20 August 1987; 15 August 1988; and 22 August 1989 the Aegean Dendrochronology Project visited the Bronze Age mound of Porsuk / Ulukışla, just north of the Cilician Gates in the Province of Niğde, Turkey, at the kind invitation of its excavator, Prof. Olivier Pelon, to take samples for dendrochronological analysis[1]. A brief mention of this work based only on the 1988 collecting season has already appeared in *Studies in Honor of Tahsin Özgüç* and is also in press in *Studies in Honor of Nimet Özgüç*. Our report, incorporating both years' work, is divided into the following sections:

1. The Porsuk master tree-ring chronology and its characteristics
2. Relative tree-ring dates with other Anatolian Bronze Age sites
3. Absolute dates based on radiocarbon wiggle-matching
4. Significance of the dendrochronological dates for the archaeological and architectural interpretation of the site as of January 1990
5. Basis for these interpretations (severely abbreviated for this report)

1. We thank Prof. Pelon and his staff for their help and encouragement and the Department for the Preservation of Cultural and Natural Heritage of the Turkish Ministry of Culture for the necessary permissions. The Aegean Dendrochronology Project is supported by the National Endowment for the Humanities, the National Science Foundation, the Institute for Aegean Prehistory, the National Geographic Society, the Samuel H. Kress Foundation, the David and Lucile Packard Foundation, the Wenner-Gren Foundation for Anthropological Research, and a number of private contributors.

1. THE PORSUK MASTER TREE-RING CHRONOLOGY AND ITS CHARACTERISTICS

Our first task at Porsuk was to build a master tree-ring chronology. This has been done for juniper (314 years), cedar (288 years), and pine (200 years) (see below). The internal crossdating is extraordinarily good, even among trees of different genera, as can be seen on the composite graph (Fig. 4 and statistical comments at the end of Section 5 below). Indeed, the "signature" between Middle Bronze Age Relative Dates (MBARD) 1317 and 1357, with remarkable minima in years 1322, 1335-1336, 1341, 1344, and 1350-1354 for all species, stands in strong contrast to the remarkably large rings at MBARD 1333 and 1357-1358, visible on the charcoal itself to the naked eye. The sensitivity with which the curves fluctuate is not surprising since the trees presumably grew on the north, and drier, slopes of the Taurus Mountains.

The Porsuk tree-ring chronology as of January 1990 (Fig. 1) is based on a total of 64 individual *trees*, although well over 200 sections were measured. The 6001 annual rings listed in the histogram in Fig. 1 are a synthesis of over 38,000 measurements[2], a robust sampling as demonstrated in the following exercise:

How to read Fig. 1 : Growth percentages for each year are shown in the left-hand table, and the number of samples from which each percentage was derived is shown in the right-hand table. For example, in the Porsuk Master Table, MBA Relative Year 1353's ring-growth was 57 % of normal and MBA Relative Year 1354's growth was 53 % of normal, an average that was derived from 36 different trees (actually over 100 separate fragments). Note also that the last two-thirds of this table is more significant than the first third because it is based on a greater number of samples. For example, in MBA Relative Years 1164 and 1165 ring-growth was only 59 % and 60 % of normal, but this observation is based on samples from only three trees. However, when one takes into account rings from the same years at Acemhüyük and Kültepe as well as at Porsuk (Table 1 in KUNIHOLM and NEWTON, 1990), one is able to say that ring-growth for 1164 and 1165 was 65 % of normal, an average based on rings from 25 different trees. The poor growth of MBARD 1164-1165 at all three sites is therefore a significant deviation from normal.

The success of our Porsuk dendrochronological effort is due to a combination of the anaerobic conditions which kept the timbers from rotting, the incomplete combustion of the wood which kept it from disintegrating into powder, our ability to collect as many samples as we did, and the selection (fortuitous for us) by the ancient builders at Porsuk of long-lived species of wood which permitted us to crossdate one timber with

2. For assistance in sample collection, preparation, and measurement we thank Marta Bechhoefer, James Crozier, Nancy Lin, Robert Pohl, and Joan Ramage.

TREE RING INDICES FOR PORSUK COMBINED

DATE	0	1	2	3	4	5	6	7	8	9
1119	0	0	0	0	0	0	0	0	0	27
1120	42	42	27	15	19	42	50	34	38	23
1130	15	19	34	34	38	23	50	27	77	69
1140	81	97	81	93	95	68	90	79	65	95
1150	140	107	118	169	108	123	99	141	160	169
1160	153	127	97	70	59	60	64	79	90	83
1170	104	103	56	62	66	68	92	123	94	78
1180	67	57	81	80	60	82	88	70	80	63
1190	58	60	88	97	100	124	120	109	72	94
1200	71	54	95	109	140	142	102	49	78	106
1210	128	88	118	89	96	128	82	82	66	80
1220	118	67	101	98	115	120	134	126	96	82
1230	72	59	73	74	65	79	49	76	91	98
1240	114	84	97	74	118	111	120	103	84	136
1250	80	91	89	114	141	140	100	103	130	110
1260	120	109	122	106	110	102	98	101	97	81
1270	117	123	74	90	88	107	103	78	77	78
1280	102	107	120	120	84	118	129	66	95	110
1290	136	119	103	92	102	100	90	81	92	86
1300	86	80	64	86	72	79	85	104	64	65
1310	92	91	95	89	81	96	120	139	128	117
1320	125	112	67	112	114	106	96	62	76	98
1330	106	116	119	143	123	54	49	96	100	73
1340	95	47	88	87	65	92	111	111	119	114
1350	80	103	86	57	53	123	165	207	184	176
1360	156	118	94	134	106	108	134	118	85	89
1370	71	76	88	68	64	55	74	76	84	94
1380	111	129	124	91	108	108	103	108	78	93
1390	59	70	108	61	99	83	77	98	117	118
1400	106	88	88	84	84	92	94	77	96	109
1410	134	100	87	80	85	86	123	78	110	86
1420	105	119	62	73	91	130	87	132	149	144
1430	127	113	135	140	157	135	151	163	180	217
1440	0	0	0	0	0	0	0	0	0	0

Saving output in G:\DATA\POR\POR.TU

NUMBER OF SAMPLES FOR PORSUK COMBINED

DATE	0	1	2	3	4	5	6	7	8	9
1119	0	0	0	0	0	0	0	0	0	1
1120	1	1	1	1	1	1	1	1	1	1
1130	1	1	1	1	1	1	1	1	1	1
1140	1	1	1	1	2	2	2	2	2	2
1150	3	3	3	3	3	3	3	3	3	3
1160	3	3	3	3	3	3	3	3	3	4
1170	4	4	4	4	4	4	4	4	4	4
1180	4	4	4	4	4	4	4	4	4	4
1190	4	4	4	4	4	4	4	4	5	5
1200	5	5	5	5	5	6	6	6	6	7
1210	7	7	7	7	7	7	8	8	8	9
1220	10	10	10	10	11	11	11	11	12	12
1230	12	12	12	12	12	12	12	12	12	13
1240	14	14	15	15	15	15	15	15	14	15
1250	15	15	17	17	18	20	21	23	24	24
1260	24	24	25	26	28	28	28	29	29	30
1270	31	32	33	33	33	33	33	33	33	33
1280	32	32	32	32	32	32	33	33	33	32
1290	32	32	32	32	31	31	30	30	30	31
1300	32	32	32	31	31	30	30	30	31	33
1310	34	34	34	34	34	35	34	34	34	34
1320	34	34	34	34	34	34	34	34	34	34
1330	33	33	33	35	35	35	35	35	35	36
1340	36	36	36	36	36	36	35	35	35	35
1350	35	35	36	36	36	36	36	35	35	35
1360	35	34	33	32	32	32	31	31	31	31
1370	32	32	31	31	30	31	30	29	28	28
1380	28	28	28	28	29	28	28	27	27	27
1390	27	27	27	26	26	26	26	26	26	26
1400	26	25	23	23	22	22	22	21	21	20
1410	19	19	19	18	18	18	18	18	18	18
1420	18	18	18	18	18	18	18	18	17	16
1430	16	13	6	2	2	2	2	2	2	2
1440	0	0	0	0	0	0	0	0	0	0

Total rings : 6001

Fig. 1. — Indices of the Porsuk Master Tree-Ring Chronology with histogram of sample abundance on the right.

another. Since the beams we found at Porsuk were not shaped by the ancient woodworkers, the existing bark provides information about the year, sometimes even the season, in which the wood was cut. In some instances (fallen roofs, collapsed walls) fire has removed as much as a century of rings, especially when the wood was not protected by the surrounding mudbrick and stone, as was the case for those beams we found still *in situ*.

It is fair to say that Porsuk is a veritable treasury of well-preserved, long-lived charcoal and therefore for the dendrochronological technique. The exploitation of the Porsuk charcoal for precise dates has only begun, and the preliminary results which follow should be interpreted as only a foretaste of what we may learn from this most interesting site.

2. RELATIVE TREE-RING DATES WITH OTHER ANATOLIAN BRONZE AGE SITES

As can be seen below, the Porsuk dates conform to the 677 year long Middle Bronze Age Relative Dating system (KUNIHOLM and NEWTON, 1990) and now form part of the 1503 year Bronze Age / Iron Age Relative Dating system (*Studies in Honor of Nimet Özgüç*, forthcoming). Thus each Porsuk date is expressed in relation to the construction dates of the Waršama Sarayı at Kültepe (MBARD 1173) and both the Sarıkaya and Hatipler Tepesi Palaces at Acemhüyük (MBARD 1231). Most of the wood at Porsuk that we have studied was cut in Relative Years 1431 / 1432, in other words 200 / 201 years after the Acemhüyük wood and 258 / 259 years after the Kültepe wood. Two exceptional pieces, Porsuk 20E and 21E, extend the chronology an additional seven years downward. The 321 year long master chronology from Porsuk thus overlaps the 469 year long Kültepe / Acemhüyük chronology by 113 years and extends it downward by 208 years, giving us a 'Middle' Bronze Age Master Chronology 677 years long, the beginning of which really extends back into the Early Bronze Age, and the end of which now connects with the Late Bronze Age and Iron Age. The new Porsuk chronology as printed in Fig. 1 is now made up of an average of *25-30 trees per year* for the two centuries following the construction of the Acemhüyük palaces rather than the 25-30 *fragments* with which we began our study.

3. ABSOLUTE DATES BASED ON RADIOCARBON WIGGLE-MATCHING

For absolute dates, in the absence of a continuous tree-ring chronology from the living trees of Anatolia back to the Bronze Age (for preliminary progress reports see KUNIHOLM, 1983; KUNIHOLM and STRIKER, 1987, 1988; and KUNIHOLM, 1989, 1990, 1991), we are still forced to rely on wiggle-matching by radiocarbon of specifically selected groups of rings (KUNIHOLM and KROMER, forthcoming). At the moment our best guess based on twenty-four radiocarbon dates is that the Porsuk chronology begins

about 1903 B.C. ±37 and ends about 1583 B.C. ±37. The Porsuk wood, situated as it is at the end of the long Bronze Age tree-ring sequence, has allowed us to bridge the gap between the two long chronologies, thereby creating a single, continuous, floating (dendro)chronology 1503 years long. The degree to which the chronology can move up and down in time is severely limited, not only by the wiggle-matched radiocarbon dates from the combined Bronze Age and Iron Age chronologies but also by a growing assortment of archaeological *termini*, as follows:

KÜLTEPE - ACEMHÜYÜK - PORSUK (MBA) RELATIVE DATING SYSTEM

MBARD 1173	Reign of Waršama, building of his palace at Kültepe. Bark.
MBARD 1231	No later than the 10th year of Šamši-Adad but possibly as early as the reign of Iakhdunlim of Mari (based on bullae found in the burned palaces at Acemhüyük). Bark.
MBARD 1401	First (= Inner) phase of the Postern at Porsuk. Bark.
MBARD 1432	Second (= Outer) phase of the Postern at Porsuk. Bark.

GORDION MIDAS MOUND TUMULUS (MMTRD) RELATIVE DATING SYSTEM

MMTRD Ring 1129 (= MBARD 1630)	From a room at Maşat (which is crossdated with the Gordion chronology) from the time of Šuppiluliumas I with imported Late Helladic IIIA pottery. No bark present.
MMTRD Ring 1764 (= MBARD 2265)	Construction date for the Midas Mound Tumulus at Gordion. Bark present.

Other data from both Bronze Age and Iron Age sites, some of them yet unpublished, are expected to supplement this preliminary list in the near future.

4. SIGNIFICANCE OF THE DENDROCHRONOLOGICAL DATES FOR THE ARCHAEOLOGICAL AND ARCHITECTURAL INTERPRETATION OF THE SITE

The double end-dates of MBARD 1431 and 1432 (1591 / 1590 B.C. ±37) for the exposed fraction of the Porsuk fortifications indicate that the wood was cut over a two-year span: from the spring / summer of Relative Year 1431 (1591 B.C. ±37) through the growing season of Relative Year 1432 (1590 B.C. ±37) but before the spring of Relative Year 1433 (1589 B.C. ±37). The elbowed postern on the west end of the mound from which most of this wood comes is an Old Kingdom Hittite construction, although it

may have continued in use in later times. Two subterranean courses of header beams on both North and South walls of the postern provide samples still in place with their bark preserved. Later modifications to the superstructure, if any, would not have necessitated alteration to the wall-footings. Moreover, in the north wall of the postern just to the east of the elbow, two more header beams, POR-78 and POR-79 (Fig. 2), were cut in Relative Year 1401 (1621B.C. ±37) again with the bark still present on both pieces (Fig. 3), suggesting that the postern had two construction phases with the eastern or inner part antedating the western or outer part by 31 years. Lacking access to the final plans and elevations for Porsuk, we can only speculate on the relationship between the two courses of subterranean header-beams in the postern's north and south walls and the fallen debris from which we collected samples which have the same cutting year as the header-beams. We presume that most if not all of the debris is not subterranean. At least three of the fallen timbers (POR-1, POR-5, and POR-12) in the postern debris seem to belong to the construction program of MBARD 1431/1432 (1591/1590 B.C. ±37). None of the debris (POR 1-12) is later than MBARD 1431/1432 as might have been expected if the postern had continued in existence for a significant length of time, thereby necessitating repairs or modifications. This raises the whole question of the time of the destruction of the postern. Here we defer to the opinions of the excavators. It is difficult for us to believe, for example, that a destruction at the end of the Late Bronze Age destroyed a postern that had been unmodified for over 500 years.

In the seven or eight years preceding Relative Year 1432 we notice a surge of unusually large annual growth-rings in many Porsuk charcoal specimens. This suggests that wood-cutting was going on at a rapid rate, thereby thinning the neighboring forests and reducing the effects of competition for sunlight and water between one tree and another. In other words, we have evidence for significant building activity at Porsuk in the decade prior to MBARD 1431/1432 (1591/1590 B.C. ±37) but not until at least two decades after the first phase of the postern in Relative Year 1401 (1621 B.C. ±37). Now that such a long dendrochronological framework is in place, almost any wood of substance excavated at Porsuk in the future should be crossdatable with it, and the serious business of working out the precise history of the development of the settlement can continue at a rapid rate. We look forward to expanded excavations on the part of our colleagues and the day when Hittite Empire wood emerges from the Porsuk excavations. The excavators assure us that Hittite Empire pottery is present at Porsuk in quantity, so there is every reason to anticipate the presence of Empire wood as well, valuable especially for site interpretation, less so for chronology extension since our wiggle-matched floating chronology extends downward to 757 B.C. ±37.

Fig. 2. — Preparation of POR - 79 for removal from its position in the scarp of the Porsuk postern.

Fig. 3. — POR - 79 after removal. The bark is still preserved on the exterior. Although the sample is entirely carbonized, the annual rings are still measurable. The cutting year was MBARD 1401 or 1621 B.C. ± 37.

5. BASIS FOR THESE INTERPRETATIONS (CATALOGUE OF SAMPLES WITH INDIVIDUAL NOTATIONS) COMMENT ON HOW TO READ THE FOLLOWING TABLES OF DATED CHARCOAL SPECIMENS

Nine pages of detailed proveniences, conditions of sample preservation, and detailed instructions on how to read and interpret the numbers are omitted in this preliminary report for reasons of space. They will be presented in the Porsuk Final Report.

PORSUK JUNIPER MASTER (PORJUNIP.TU) M = 314 **MBARD 1119 - 1432B (= 1590 B.C. ±37)**

Includes: POR-1A-F, 2A-M, 3AB, 5A-F, 6AB, 7ABC, 8AA, 8AB, 8AC, 8AD, 8B ABC, 14A-E&G, 21B, 26AB, 28AB, 57B, 81CE, 001, 002, 003, 004, 112, 005, A5 ABC, B4 AB, and B'4 A-D.

PORSUK CEDAR MASTER (PORCEDAR.TU) M = 288 **MBARD 1144 - 1431W (= 1591 B.C. ±37)**

Includes: POR-4A, 9A-E, 11A, 12A-M, 16ABC, 18A, 21A, 21F, 23ACD, 31A-D, 47A-D, 51A, 78A-B, 79A, 81FGH, and 113A.

Note: POR-78 and POR-79 both preserve bark in Relative Year 1401.

PORSUK PINE MASTER (PORPINE.TU) M = 200 **MBARD 1240 - 1439vv (= 1583 B.C. ±37)**

Includes: POR-15ABE, 15F, 18D, 19B, 20A, 20B-E, 21CD, 21E, 81A, 81B, and 91A-D.

Note that samples POR-20 and 21 with proveniences given as "destruction level 1 on the soil" are the only two pieces at Porsuk with rings preserved beyond Relative Year 1432.

PORSUK COMBINED MASTER (POR.TU) M = 321 **MBARD 1119 - 1439vv (= 1583 B.C. ±37)**

The Porsuk juniper, cedar, and pine masters have been combined with the one dated piece of fir, POR-22B-D (1315+p-1362), to make the Porsuk combined master. This master is not used for crossdating as it contains trees of different species; however, it does give an accurate histogram showing the building phases at the site.

COMMENT REGARDING SPECIES IDENTIFICATION AND MULTIPLE SAMPLES

Pieces of the same specimen (as excavated) were found to belong to trees of different species. (We have sent selected samples of Porsuk charcoal to the Swiss Federal Forestry Research Institute and the Institute for Quaternary Wood in Zürich for confirmation of their identification.) For instance, Porsuk Wood Sample 81 really represents five different trees of three different genera. Therefore various pieces of POR-81

appear in all three of the master chronologies. Moreover, several samples, given different numbers at the time of collection from the depot, are certainly from the same original tree. In the master chronologies each tree is given a value of 1, regardless of how many fragments come from it. Thus the characteristics of no one tree may dominate the others.

QUALITY OF CROSS DATING FOR PORSUK MASTER CHRONOLOGIES[3]

ACEMHÜYÜK JUNIPERS	ACMJUNIP (MBARD 1069-1232) (N = 164)					
ACEMHÜYÜK PINES	*t* = 6.04 tc = 75.2% D = 152.40 n = 114	ACMPINE (MBARD 1118-1231) (N = 114)				
ACEMHÜYÜK CEDARS	*t* = 6.93 tc = 65.6% D = 108.40 n = 164	*t* = 4.05 tc = 69.0% D = 76.99 n = 114	ACMCEDAR (MBARD 910-1239) (N = 330)			
PORSUK JUNIPERS	*t* = 6.68 tc = 65.5% D = 103.50 n = 114	*t* = (2.80) tc = (58.9%) D = (24.96) n = 113	*t* = 3.19 tc = (57.5%) D = (23.92) n = 121	PORJUNIP (MBARD 1119-1432) (N = 314)		
PORSUK PINES	NO OVERLAP	NO OVERLAP	NO OVERLAP	*t* = 9.23 tc = 71.9% D = 212.14 n = 193	PORPINE (MBARD 1240-1439) (N = 200)	
PORSUK CEDARS	*t* = 4.76 tc = 75.0% D = (119.03) n = 89	*t* = (1.91) tc = 63.2% D = (25.22) n = 88	*t* = 3.36 tc = (59.0%) D = (30.04) n = 96	*t* = 14.43 tc = 74.6% D = 354.54 n = 288	*t* = 7.42 tc = 67.5% D = 130.07 n = 192	PORCEDAR (MBARD 1144-1431) (N = 288)

Note: The crossdating is as good as any we have found in Anatolia, even across many kilometers and between differing species of trees. After this report was written, the Porsuk chronology was found to crossdate with the chronologies from Konya-Karahöyük and Gordion. These additional statistics will be presented in the Porsuk Final Report.

3. These are standard statistical tests. The non-parametric trend coefficient (tc) or percentage of agreement is described by B. HUBER in J. FLETCHER, ed., *Dendrochronology in Europe, British Archaeological Reports, Supplementary Series* 51 (1978) 23. The parametric *t*-test is described by M.G.L. BAILLIE and J.R. PILCHER, "A Simple Crossdating Program for Tree-Ring Research," *Tree-Ring Bulletin* 33 (1973) 7-14. The D-Score which combines these two tests (significant only if the overlap or *n* - is over 100 years) is described by B. SCHMIDT, *Dendrochronologie und Ur- und Frühgeschichte*, Köln, Habilitation thesis, 1987, 13. At Porsuk, except where the overlap between curves is short (*i.e.*, under 100 years), the fits are excellent, both visually and statistically. Scores that are not statistically significant (99.5 % confidence level) are shown in parentheses ( ).

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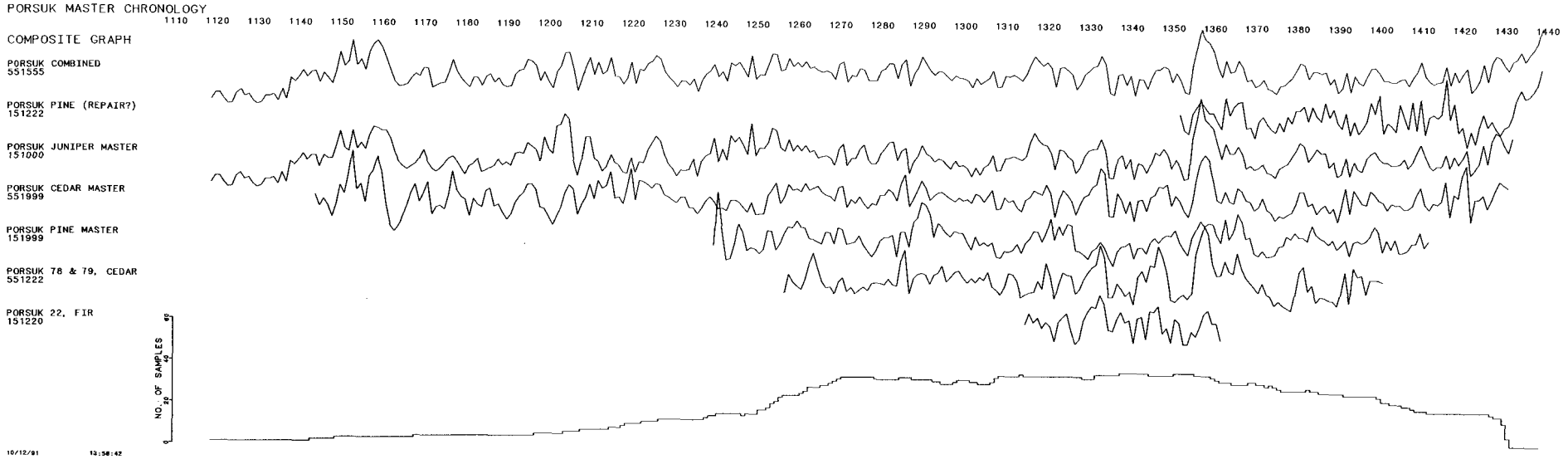

Fig. 4. — Composite Graph of the Porsuk Ring-Indices by Genera. Note the good quality of the fit from year to year.