Counts with pulse height analyzer channel numbers <4 (out of a 1 to 16 range) were eliminated to avoid contamination from UV emissions.
6. The x-ray emissions observed in association with the K and P2 impacts appear to display a longitude dependence similar to that of the UV aurora and to that postulated for the normal x-ray aurora (*2*). The longitude region within which they occurred was not visible to ROSAT at the times of the R and S fragment impacts, however, which may explain why no enhanced counts were detected in association with these events. ROSAT may have detected a weak signature near the time of the W impact; however, data collection did not start until about 6 min after the W impact. The relatively weak W signature may represent the waning tail of a more active x-ray emission period.
7. The Kolmogorov-Smirnov and Kuiper tests used in our analysis of the K and P2 observations are described in W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, *Numerical Recipes in FORTRAN: The Art of Scientific Computing* (Cambridge Univ. Press, Cambridge, ed. 2, 1992), pp. 617–622. Although we used both tests, we cite only the Kuiper statistics, which are more conservative (generally by a factor of 10) than the Kolmogorov-Smirnov statistics.
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10. ROSAT's normal pointing uncertainty of 5 arc sec (1σ) was considerably improved upon for our Jupiter observations by the fortuitous presence of two astrophysical x-ray point sources within the 40–arc min–diameter field of view. High-precision positions for the optical counterparts to the two sources near the time of the impacts were kindly provided to us by O. A. Naranjo (personal communication). One of the sources is at right ascension (RA) 14 hours, 13 min, and 5.14 s and declination (DEC) 12°, 1 arc min, and 24.4 arc sec and is identified as the star GQ Vir. The other source is at RA 14 hours, 12 min, and 39.1 s and DEC 12°, 9 arc min, and 10.8 arc sec and is unidentified in the visible. Using these positions, we corrected the ROSAT data by shifting the centroided counts from these two sources to the above positions. The final pointing accuracy appears to be good to within ±1.5 arc sec.
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Microchronology and Demographic Evidence Relating to the Size of Pre-Columbian North American Indian Populations

Dean R. Snow

Recent estimates for the size of the aggregate North American Indian population in A.D. 1492 vary from about 18 million to less than 2 million. The unusually favorable archaeological characteristics of Mohawk Iroquois sites in eastern New York have allowed a detailed demographic reconstruction of one case for the period A.D. 1400 to 1776. The case indicates that exogenous epidemics did not reach the region until the 17th century and supports arguments favoring the lower populations estimates for North America as a whole.

The sizes of pre-Columbian populations in the Americas have been the subjects of scholarly debate in recent years (*1*). The debate has been prompted mainly by the hypothesis that unrecorded exogenous pandemics reduced American Indian populations by very large fractions during the 16th century (*2*). The hypothesis presumes that the earliest population estimates available from documentary sources for North American Indian populations are, more often than not, postepidemic counts, and that numbers must have been higher prior to A.D. 1492. How much higher depends on the severity and ubiquity of the pandemics presumed to have occurred between A.D. 1492 and the earliest available counts (*3*).

A remnant population of 2000 implies a preepidemic population of 10,000 if 80% mortality is assumed, but the reconstructed initial figure is twice that size if the mortality rate is raised by only another 10%. Thus, for North America alone, one scholar puts the estimate at 18 million for A.D. 1492, whereas several others argue for a figure about a tenth that size (*2*, *4*, *5*).

There is no evidence for exogenous pandemics in northeastern North America before A.D. 1616, even though they began a century earlier in areas of Spanish settlement around the Caribbean (*6*). Two of the reasons for the lag appear to be the quarantine effects of small crew sizes and long crossing times before A.D. 1600. However, the most important factor was the absence of children in parties of Europeans making contact with American Indians outside the sphere of Spanish colonization. Smallpox and the other exogenous epidemics that devastated American Indian populations were childhood diseases in Europe at the time; nearly all European adults were survivors of these childhood illnesses who enjoyed lifelong immunity and were not contagious to the susceptibles they might contact. The Spanish brought children with them early, with devastating effects. Children did not accompany French, Dutch, and English colonists until much later.

If timing was important, so too was the ubiquity of diseases. Although it is an essential component of any scenario involving dramatic widespread population declines in the 16th century, it has not been demonstrated that every epidemic became a continent-wide pandemic. The available evidence is more consistent with patterns of local and regional epidemics that affected some parts of the continent decades (sometimes centuries) before others (*4*, *5*).

The Mohawk Indian nation was and is one of the constituent nations of the League of the Iroquois. Data from the Mohawk archaeological site sequence in New York State provide support for the lower current estimates of pre-Columbian population sizes (Fig. 1). The Mohawks practiced a northern swidden form of horticulture that entailed village relocations every decade or two. Mohawk villages were compact, usually palisaded, and regular in their construc-

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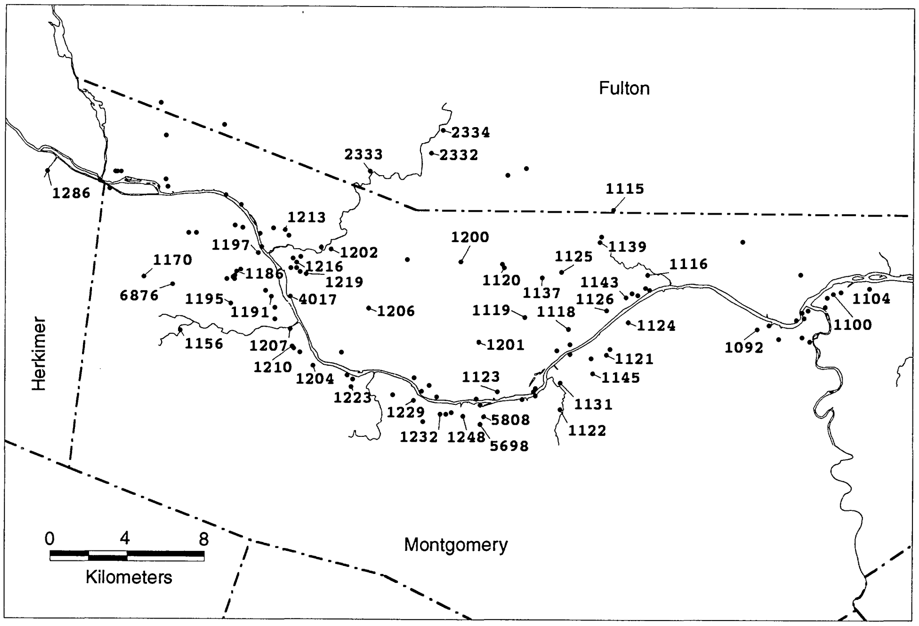

Fig. 1. Mohawk sites in and around Montgomery County, New York. Village sites used in this study, most of which are shown, are identified by their site numbers. Virtually all of the sites fall into the critical time span.

Table 1. Thirty-eight radiocarbon age determinations on *Zea maize* kernels. The ages, given in years before present (years B.P.), have been corrected for stable carbon isotopes, and the dates were calibrated with the Calib 2.0 and 3.0 programs (*12*).

Lab number	^{14}C age (years B.P.)	Site name	Calibrated dates A.D. -1σ (mean[s]) $+ 1\sigma$
A-6064	210 ± 35	Caughnawaga	1651 (1662) 1955
A-6065	340 ± 25	Wormuth	1488 (1516, 1599, 1618) 1631
AA-6416	385 ± 50	Wormuth	1439 (1468) 1622
AA-6417	300 ± 50	Garoga	1494 (1532, 1541, 1637) 1650
AA-6418	315 ± 60	Klock	1483 (1527, 1560, 1631) 1649
AA-6419	405 ± 50	Smith-Pagerie	1435 (1448) 1493
AA-6420	235 ± 55	Oak Hill #1	1639 (1654) 1955
AA-6421	300 ± 50	Cayadutta	1494 (1532, 1541, 1637) 1650
AA-6423	400 ± 50	Otstungo	1435 (1450) 1616
AA-6424	315 ± 50	Rumrill-Naylor	1488 (1527, 1560, 1631) 1646
AA-6425	380 ± 50	Elwood	1440 (1476) 1640
AA-6426	80 ± 55	Horatio Nellis	1667 (1897, 1908, 1955) 1955
AA-7398	380 ± 55	Otstungo	1439 (1476) 1627
AA-7399	345 ± 55	Otstungo	1450 (1513, 1602, 1615) 1640
AA-7400	415 ± 50	Otstungo	1432 (1444) 1490
AA-7401	365 ± 50	Otstungo	1444 (1488) 1633
AA-7402	410 ± 50	Otstungo	1434 (1446) 1491
AA-7403	410 ± 60	Garoga	1431 (1446) 1610
AA-7404	520 ± 75	Klock	1326 (1415) 1439
AA-7405	430 ± 50	Smith-Pagerie	1428 (1441) 1482
AA-7406	277 ± 51	Oak Hill #1	1521 (1643) 1657
AA-7407	367 ± 52	Cayadutta	1443 (1488) 1633
AA-7409	383 ± 47	Rumrill-Naylor	1440 (1472) 1622
AA-7410	409 ± 49	Elwood	1420 (1446) 1635
AA-7411	144 ± 52	Horatio Nellis	1650 (1683, 1732, 1807, 1933, 1955) 1950
AA-7413	435 ± 50	Turnbull	1426 (1440) 1475
AA-7415	335 ± 35	Chapin	1486 (1518, 1596, 1620) 1637
AA-7417	290 ± 37	Briggs Run	1522 (1640) 1650
AA-7689	557 ± 58	Cayadutta	1317 (1334, 1337, 1406) 1424
AA-7690	415 ± 56	Cayadutta	1430 (1444) 1492
AA-7691	360 ± 40	Turnbull	1449 (1490) 1630
AA-7693	315 ± 40	Briggs Run	1492 (1527, 1560, 1631) 1644
AA-7695	431 ± 49	Garoga	1428 (1441) 1479
AA-7697	288 ± 49	Elwood	1517 (1640) 1653
AA-7732	370 ± 48	Cromwell	1443 (1487) 1629
AA-7733	488 ± 52	Cromwell	1409 (1426) 1441
AA-8369	635 ± 45	Briggs Run	1282 (1302, 1372, 1382) 1392
AA-8370	585 ± 40	Garoga	1304 (1329, 1348, 1392) 1409

tion, such that we have been able to derive reasonably accurate population sizes from measurements of village sizes (*7*). The periodization of about 60 site components has allowed us to aggregate village populations into Mohawk population levels for each of 16 brief periods in the span of A.D. 1400 to 1776. We can therefore track one American Indian population through the processes of contact with Europeans and epidemic depopulation.

The Mohawk case is complicated by sociopolitical processes that were also operating in the 16th century. In the previous century, there were a larger number of small Mohawk communities, usually having populations of 200 or less. Warfare with other nations caused the Mohawks to nucleate into a smaller number of larger villages built on more defensive sites in the 16th century. If the large increase in average village size is not taken into consideration, the decrease in the number of villages can be misinterpreted as evidence of rapid population decline. The shift also entailed a compacting of the village populations (*8*, *9*). Whereas in A.D. 1450 there were about 20 m^2 of village area per inhabitant, that number shrank to 12 m^2 by A.D. 1550 (*7*). These ratios have been derived from measurement of several Iroquois villages for which the numbers of inhabitants are independently known.

The case is also complicated by migration. Net immigration augmented fertility and swelled the Mohawk population in some periods. Several investigators have used ceramics and trace elements to document these movements (*10*). Net emigration, on the other hand, combined with mortality to increase the rate of decline in other periods.

The Mohawk case is still further complicated by the difficulty inherent in working out archaeological sequences in which occupation periods may have been as short as a decade or less and village communities sometimes reoccupied previously used sites. The sequence has been based mainly on analyses of native ceramics. However, recent advances in our understanding of the histories of key trade items have clarified the later part of the sequence (*9*, *11*).

Clarification of the earlier part of the sequence has been aided by radiocarbon age determinations carried out by the accelerator mass spectrometry (AMS) laboratory at the University of Arizona. Carbonized wood samples are unreliable because they might be decades older than the hearths from which they are taken. Consequently, 38 age determinations were obtained on kernels of *Zea maize*, which were most likely carbonized and deposited within a year of their growth. The resulting dates were corrected for stable carbon isotopes and calibrated with the Calib 2.0 and 3.0 programs (*12*) (Table 1).

Table 2. Site period revisions based on radiocarbon age determinations.

Site number	Site name	Expected age (A.D.)	Revised age(s) (A.D.)
1116	Caughnawaga	1679–1693	1679–1693
4017	Wormuth	1500–1525	1450–1525
1156	Otstungo	1400–1525	1450–1525
2333	Klock	1550–1600	1400–1525, 1540–1565
2334	Smith-Pagerie	1575–1600	1400–1525, 1560–1580
1186	Oak Hill #1	1635–1646	1635–1646
5698	Rumrill-Naylor	1635–1646	1400–1525, 1635–1646
1229	Horatio Nellis	1646–1666	1646–1666
1115	Cayadutta	1515–1580	1400–1525, 1525–1545
1586	Turnbull	1150–1300	800–1150
1170	Elwood	1400–1500	1450–1500
1121	Cromwell	1626–1635	1400–1525, 1626–1635
1118	Briggs Run	1615–1626	1400–1525, 1614–1626
2332	Garoga	1550–1600	1400–1525, 1525–1545

The AMS age determinations allowed us to improve the earlier part of the chronology somewhat and to calibrate it calendrically. More importantly, it confirmed cases where ceramic evidence had previously suggested that 16th- and 17th-century villages were constructed over much smaller 15th-century village sites (Table 2). The sequence is reported in detail elsewhere (9).

Table 3 summarizes Mohawk village sites and their probable aggregate population sizes by their periods of occupation. Because these figures are based on maximum village sizes, they probably reflect population sizes at the ends of periods when the population was growing or at the beginnings of periods when it was declining.

Because the search for Mohawk villages has been intense for over a century and because they were usually located in agriculturally productive settings that are heavily farmed today, it is unlikely that many sites remain undiscovered. Thus, Table 3 probably accounts for most, if not all, of the Mohawk population residing in their traditional territory between A.D. 1400 and 1776.

The total Mohawk population was probably no more than 1230 around A.D. 1492. It grew steadily, but not dramatically, through the 16th century, even though the number of villages simultaneously occupied was declining. There was more rapid growth near the end of the century, probably the result of an influx of immigrants from Jefferson County and elsewhere in the Saint Lawrence River drainage (*11, 12*).

Table 3. Mohawk villages and aggregate populations by period, A.D. 1400 to 1776.

Period	No. of villages	Population
A.D. 1755–1776	3	640
A.D. 1712–1755	4	580
A.D. 1693–1712	7	600–620
A.D. 1679–1693	3	1100
A.D. 1666–1679	4	2000
A.D. 1657–1666	7	2304
A.D. 1646–1657	6	1734
A.D. 1640–1646	3	1760
A.D. 1635–1640	4	2835
A.D. 1626–1635	4	7740
A.D. 1614–1626	5	6225
A.D. 1580–1614	4–7	2653–4575
A.D. 1560–1580	2	2020
A.D. 1545–1560	2	1570
A.D. 1525–1545	2	1490
A.D. 1400–1525	~13	1070–1230

The Mohawk population spiked after the Dutch established a trading post at what is now Albany in A.D. 1614. The spike was produced by a continuing influx of migrants attracted to the Mohawk Valley at this time, especially a community of Oneida immigrants. Oneidas apparently established their own village at site 1197 (Fig. 1) and remained there for almost two decades. Similar consolidations took place in other parts of what are now New York and Ontario for other reasons, but in no case would such local population spikes have been possible had epidemics begun in this period or in the decades leading up to it.

The first smallpox epidemic struck the Mohawks in A.D. 1634, and by the following year they had moved to a new set of smaller villages. The archaeological evidence indicates that the Mohawk population declined by 63% in less than a year (Table 3). Declines of such magnitude are attested to by both contemporary documents and similar cases in the 20th century (9). The decline continued through the succeeding decades as epidemics of other diseases afflicted them, and smallpox returned cyclically to infect susceptible children born after the previous appearance of the disease.

Population decline continued to be offset somewhat by voluntary immigration from areas being settled by Europeans as well as by the incorporation of war captives. One village was apparently occupied by about 570 Huron immigrants from A.D. 1657 to 1679. The reversal was temporary, for Jesuit missionaries encouraged the Hurons and Catholic Mohawks to move with them to Canada by A.D. 1679. Thereafter, population decline continued steadily until the final departure of Mohawks from the valley during the American Revolution.

Mohawk village population sizes can be derived from the A.D. 1635 journal of Harmen van den Bogaert when it is used in concert with archaeological data (*7, 13*). However, the earliest explicit documentary reference to their population size is a mention of three villages and 700 to 800 warriors in a Jesuit source from A.D. 1642 or 1643 (*14*). If, as suggested by a consensus of 17th-century sources (7), warriors accounted for a quarter of the population, this leads to total population of 2800 to 3200 Mohawks at that time. This figure is consistent with the archaeological data for the years just after the first epidemic.

If, as has been advocated by a few investigators (2), one assumes that there were unrecorded pandemics in the 16th century and that the earliest documented figures account for only 10% of the pre-Columbian population, an A.D. 1492 population of 28,000 to 32,000 Mohawks is projected. However, the Mohawk case shows that there is no archaeological support for such a high figure. There is clear evidence for local development of the Mohawk population from A.D. 1400 and before, no evidence of large migration into the area in the 15th century, and no evidence of village sites that accommodated more than 1230 people at that time. There is no support for the notion that ubiquitous pandemics swept the region in the 16th century.

There are few regions in North America where demographic change over time can be measured by archaeological means as well as has been possible in the Mohawk case. Nevertheless, it is reasonable to argue that if there were as many as 18 million Indians in North America in A.D. 1492, archaeologists should be able to identify enough contemporary sites to accommodate at least a large fraction of them. Proponents of the higher estimates have not demonstrated that the sites exist to house that many people. It is reasonable to conclude that Ubelaker's estimate of just under 2 million (5) is closer to the mark.

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Exceptionally Thermally Stable Polyimides for Second-Order Nonlinear Optical Applications

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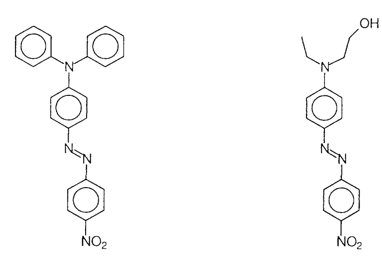
The thermal stability of the electric field induced poled order in a new class of second-order optically nonlinear polymers, "donor-imbedded" side-chain polyimides containing no flexible connectors or tethers to the nonlinear optical (NLO) chromophore, is investigated. In these polymers, the electron-donor part of the chromophore is a diaryl-substituted amine that is incorporated as a part of the polymer backbone. The donor-imbedded systems used in this study have exceptional chemical stabilities at elevated temperatures (350°C) and impressive poled order stability at extremely high temperatures (300°C). In both respects, they were significantly more stable than a true side-chain polyimide with a similar NLO-active chromophore covalently linked to the polymer backbone by a flexible tether group.

Second-order optically nonlinear polymers have potential uses for second-harmonic generation (SHG) (frequency doubling) (*1*) and for very high speed optical switching and modulation (*2*). In order to realize this potential, however, the polymers must withstand temperature excursions during processing that may approach or exceed 300°C and prolonged operation temperatures of up to 100°C. Here we describe a class of exceptionally stable optically nonlinear polyimides some of whose members can be used for periods longer than 1000 hours at temperatures of 225°C and above without any measurable decrease in nonlinearity and that can be held at temperatures greater than 300°C for tens of minutes without thermal degradation or substantial loss in optical nonlinearity.

An electrooptic polymer consists of a dipolar chromophore either dissolved in or chemically attached to a polymer backbone (*3*). The system is made optically nonlinear by raising the polymer-chromophore system above its glass transition temperature T_g in the presence of an electric field. The electric field orients the dipolar chromophores, and after orientation the system is returned to a lower operating temperature before removal of the poling field. In order for the optical nonlinearity, as measured by the electrooptic coefficient r (*4*), to be stable during processing and prolonged use, the chromophores must be chemically stable at all temperatures that the system encounters and the orientation of the chromophores must be maintained at these temperatures as well. Recently a class of nonlinear optical (NLO) chromophores containing diarylamino donor substituents with substantial optical nonlinearity and high thermal stability has been described (*5*). Chromophore **1** is such a chromophore. It is a variant of the well-known



1 **2**

dye molecule Disperse Red 1 (chromophore 2) which is stable up to temperatures of 309°C. The substitution of the two phenyl groups for the alkyl groups increases the stability to 393°C. In both cases, the thermal stability is estimated by differential scanning calorimetry (DSC) at a heating rate of 20°C per minute. The value of the decomposition temperature obtained in this way may be high by as much as 60° to 80°C when compared to measurements made by following the chromophore disappearance by monitoring changes in the ultraviolet (UV) absorption spectrum after heating (*6*). The DSC measurements have, however, proved to be a quick way of obtaining the relative ordering. The greatly enhanced stability of the diphenylamino-substituted chromophores over their dialkylaminophenyl-substituted analogs is a surprising, but apparently quite general, phenomenon (*5*). The stability of the electric field–poled ordering can be improved by incorporating these chemically stable chromophores into polymers such as polyimides that have very high T_g's (*7*).

Incorporation of NLO chromophores into polymers can be accomplished in several ways: by dissolution in a polymer host (a guest-host system); by covalent bonding of the chromophore to the polymer by a flexible tether group (a side-chain system); or by incorporation of the chromophore into the polymer backbone (a main-chain or imbedded side-chain system). Each of these systems has its own set of advantages and disadvantages, but it is generally believed that covalently bonded polymers, either side chain or main chain, will ultimately be necessary for use in practical devices.

We report the exceptional thermal stability of the electric field–induced (poled) order in a class of polyimides in which the electron donor group of the chromophore is incorporated directly into the backbone of

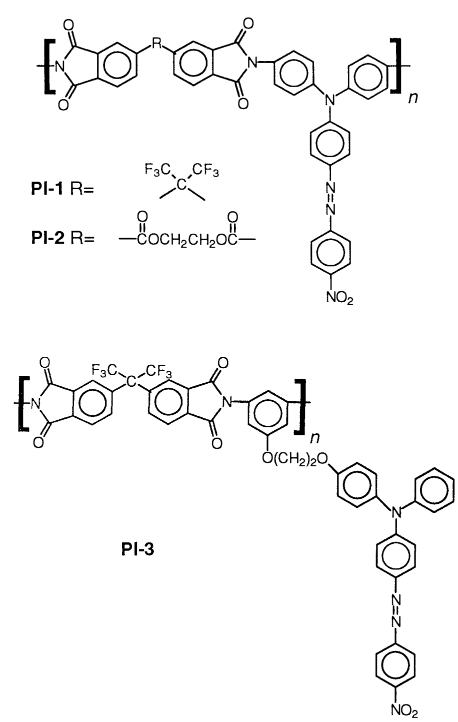


Fig. 1. Chemical structures of **PI-1**, **PI-2**, and **PI-3**.

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