inferred to have produced shocked materials found in the upper layer of some K/T boundary deposits, mainly because its radiometric age (66 m.y.) is compatible. Short, in 1966 [1], was the first to show that Manson is an impact crater through casual analysis of 22 samples from a 1953 drillhole (2-A). These samples have now been studied in detail, with these key results: (1) The lithology of clasts within 2-A is dominantly granitic. (2) Most quartz is strongly shocked (many planar deformation features, PDFs) and shows a pervasive alteration (clay minerals?; iron stain). (3) A unique texture [single crystals broken into hundreds of small fragments (polycrystalline)] occurs in some heavily shocked quartz. (4) Feldspars display a wide range of shock features from multiple PDFs to incipient melting (internal flow) and extensive recrystallization. Table 1 summarizes the major shock features arranged in stages of progressive shock metamorphism for the three principal minerals: quartz, feldspar, and biotite.

The predominant mode of PDF occurrence in quartz within leucogranitic clasts, and in most quartz fragments in matrix material, is marked by light, orange-brown to grayish brown in plane-transmitted light, and a deeper reddish brown, with reduced birefringence, cross-polarized light. At high magnification, the alteration consists of tiny specks of unknown identity that often obscure but do not destroy the sets of PDFs. The effect under the microscope sometimes resembles the "texture" of toasted bread. This hallmark of Manson shocked quartz is rarely seen in shocked quartz from other impact structures (occasional in materials examined by NMS from West Hawk Lake and Steen River in Canada). Sharpton et al. [2] describe similar quartz in their examination of Manson materials, stating the origin of this alteration to be due to in-crater postimpact hydrothermal alteration; if so, such a condition would not be diagnostic of shocked quartz grains in K/T deposits and is therefore not a criterion for relating these deposits to the Manson event. Single (larger) crystals of "toasted" quartz contain an average of 5.5 sets of PDFs whose principal crystallographic orientation is π1012 (ω1013 is second most common). Much less frequent in clasts and matrix grains are untoasted but decorated PDFs in quartz, with ω predominant in the average 2.2 sets per grain.

In some strongly shocked leucogranites, and in occasional matrix fragments, single crystals have been broken into numerous small (100 μm) interlocking quartz grains (toasted), containing an average of only 1.4 PDF sets, in which ω is prevalent. These sets do not cross individual micrograin boundaries and orientations vary between grains. This highly distinctive texture, which we interpret as shock-induced shattering of single crystals accompanied by rotations, may be unique to Manson: A similar texture has been described by Schreyer [3] in Vredefort Central Core granites, but in those quartzes the PDFs pass across grain boundaries. In highly shocked Manson quartz, recrystallization may completely remove PDFs and the toasted effect is absent.

Manson feldspars show a range of PDFs, some resembling those in quartz, others arranged en echelon in alternating albite twins, others concentrated in deformation bands. Feldspars may partially isotropize or display internal flow banding in thetomorphic crystals or may be recrystallized. Biotite responds by intricate kinking progressing through nearly complete decomposition. Undevitrified glass is rare in 2-A.

In 1991–1992, the U.S. Geological Survey drill-cored 12 holes to depths under 380 m along a zone from crater center to assumed rim. Hole M-1 lies about 4 km northeast of 2-A within the central peak (probably a ring). Materials in the upper 100 m or so are mainly shales and some carbonates that show indecisive shock effects except for occasional melting. Crystalline clasts below the sedimentary materials have proportionately less leucogranites and more dioritic and amphibolitic clasts. The variety and characteristics of shock effects in these rocks are often notably different from those in crystalline 2-A clasts.

TABLE 1. Stages of progressive metamorphism of 2a Manson materials.

Stage	Quartz	Feldspar	Biotite
0	unshocked	unshocked	unshocked
I	1–3 PDFs	PDFs (quartzlike)	kinked
II	3–6 PDFs moderately to intensely "toasted"	en echelon PDFs mainly in albite	lenticular kinks twins
III	polycrystalline quartz aggregates 1–2 PDFs/domain	alter. alternate twin lamellae	reduced birefringence/ pleochroism
IV	incipient isotropization	birefringence reduction early isotropization	partial degradation (brown phase)
V	incipient melting and flow	incipient melting and flow	extensive decomposition dark brown, micro-opaques
VI	recrystallization (?) without PDFs	recrystallization (polycrystalline aggregate) "feather" texture	recrystallization

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EVIDENCE FOR EXTREMELY-HIGH-TEMPERATURE MELTING IN THE SOLAR NEBULA FROM A $CaAl_4O_7$-BEARING SPHERULE FROM MURCHISON. S. B. Simon[1], L. Grossman[1,2], A. M. Davis[2], J. R. Beckett[3], and L. Chamberlin[3], [1]Department of Geophysical Sciences, University of Chicago, Chicago IL 60637, USA, [2]Enrico Fermi Institute, University of Chicago, Chicago IL 60637, USA, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena CA 91125, USA.

We have recovered a unique refractory spherule (B6) from the Murchison C2 chondrite. Approximately 140 μm in diameter, it is concentrically zoned, with an outer rim sequence, from outermost to innermost, of aluminous diopside (10 μm thick), anorthite (3 μm), and melilite (3 μm). Inside the melilite layer is a 7-μm-thick, nearly pure (except for a single, diverging-inward spray of hibonite crystals) layer of spinel. Inward from this layer is a 22-μm-wide zone of hibonite (~5.5 wt% TiO_2) + spinel, in which hibonite laths, 1–4 μm across and up to 10 μm wide, are predominantly radially oriented and enclosed in spinel. Inward from this zone, presumably at the core of the inclusion, are $CaAl_4O_7$, occurring as anhedral grains ~10 μm across, and minor perovskite. Some of the hibonite laths protrude into the $CaAl_4O_7$.

The sequence of mineral assemblages from the spinel shell inward parallels that expected for fractional crystallization of a melt of the composition of B6. Based on this, the inclusion's spherical shape and its texture (radially oriented hibonite laths, including a diverging-inward spray; laths enclosed in spinel and protruding into $CaAl_4O_7$) we conclude that the oxide phases in B6 crystallized from a liquid. The spinel layer indicates that at least some of the spinel was molten; from the bulk composition, calculated liquidus phase relations in the system Al_2O_3-MgO-CaO [1], and the amount of spinel contained in the layer, we infer a melting temperature >2000°C. This is >500° higher than the maximum temperature at which any condensed major phase is stable at 10^{-3} atm in a gas of solar composition, but we see no evidence of evaporation. First, the inclusion has a Group II REE pattern, rather than a Group III or an ultrarefractory pattern, which could reflect devolatilization. Second, although evaporation of molten (but not solid) Mg_2SiO_4 leads to Mg isotopic mass fractionation [2], we found the Mg isotopic composition of spinel and hibonite in B6 to be essentially normal ($\Delta\,^{25}Mg = 0 \pm 2.5‰$). This means that no more than ~15% of the Mg could have evaporated, which, by analogy with experiments with forsterite at 2050°C [2], suggests that the melt was exposed to the solar nebula for a very short time, perhaps as little as 2 min. This could indicate rapid formation of the spinel shell in B6, sealing off the molten interior from the solar nebula. Evaporation of solid spinel could have occurred, but would probably not fractionate Mg isotopes significantly.

Evidence of an unusually-high-temperature history is preserved in the spinel of B6. It averages 1.7 ± 0.4 mol% excess Al_2O_3 relative to $MgAl_2O_4$, unlike the stoichiometric (within analytical error) spinel found in most CAIs. Much larger Al_2O_3 solubilities than observed in B6 spinel have been produced in synthetic systems at temperatures as low as 1300°C [3]. In our crystallization experiments, excess Al_2O_3 ranges from 2 mol% in spinel equilibrated with melilite + hibonite + liquid at 1400°C to 30 mol% in spinel equilibrated with liquid at 1499°C. In corundum-bearing runs, excess Al_2O_3 in spinel increases from 12 mol% at 1349°C to 24 mol% at 1450°C, consistent with [3]. Excess Al_2O_3 in spinel is directly correlated with $a_{Al_2O_3}/a_{MgO}$ based on experiments with solids [4]; it should also be correlated with $a_{Al_2O_3}/a_{MgO}$ of coexisting liquids, and with temperature at constant $a_{Al_2O_3}/a_{MgO}$ [1]. Spinels in our experiments have large excess Al_2O_3 contents because coexisting liquids have $a_{Al_2O_3}/a_{MgO} > 6$ [1]. The bulk composition of B6 and residual liquids produced by crystallization of spinel from this composition have $a_{Al_2O_3}/a_{MgO} \sim 1$ [1], resulting in lower excess Al_2O_3 in B6 spinel than in our synthetic spinel. In type B inclusions, liquids with which spinel equilibrated also had $a_{Al_2O_3}/a_{MgO}$ ratios ~1, but because equilibration temperatures were ≤1500°C, this spinel has negligible excess Al_2O_3, consistent with the results of [4]. The larger amounts of excess Al_2O_3 in B6 spinel indicate that its equilibration temperature was substantially higher than in type Bs (i.e., ≥ 1500°C), consistent with the above observations.

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CROSS-SECTION MEASUREMENTS FROM 40 TO 450 MeV FOR THE PRODUCTION OF ^{14}C FROM SILICON AND OXYGEN: BETTER ESTIMATES FOR COSMOGENIC PRODUCTION RATES. J. M. Sisterson[1], A. J. T. Jull[2], A. Beverding[3], A. M. Koehler[1], C. Castaneda[4], J. Vincent[6], D. J. Donahue[2], P. A. J. Englert[3], C. Gans[3], J. Young[5], and R. C. Reedy[7], [1]Harvard Cyclotron Laboratory, Harvard University, Cambridge MA 02138, USA, [2]NSF-Arizona AMS Facility, University of Arizona, Tucson AZ 86721, USA, [3]Department of Chemistry, San Jose State University, San Jose CA 92521, USA, [4]Crocker Nuclear Laboratory, University of California, Davis CA 95616, USA, [5]Department of Physics, California State University, Chico CA 95929, USA, [6]TRIUMF, 4004 Westbrook Mall, Vancouver BC V6T 2A3, Canada, [7]Space Science and Technology Division, Los Alamos National Laboratory, Los Alamos NM 87545, USA.

Cosmogenic nuclides in extraterrestrial materials allow studies to be made of the solar cosmic ray (SCR) flux over time periods in the past [1], the constancy of the galactic cosmic ray flux, and even the sample's recent history. To interpret such measurements, especially for SCR-produced nuclides, it is essential that the cross sections for the reactions of all cosmic ray particles with each constituent of the sample be very well known. Approximately 98% of SCR particles are protons and their interactions are the major source of cosmogenic nuclides in the surface layers of extraterrestrial materials. Until the development of accelerator mass spectrometry (AMS), few of the needed cross sections were known well enough to be used with confidence. Now, using thin-target irradiations and the improved sensitivity of AMS, good cross-section measurements for the production of these cosmogenic radioisotopes can be made.

Preliminary cross-section measurements for $^{16}O(p,3p)^{14}C$ and $^{nat}Si(p,x)^{14}C$ made at the Harvard Cyclotron Laboratory (HCL) using SiO_2 and Si targets have been reported for the proton energy range 65–160 MeV [2]. They confirm earlier data for the $^{16}O(p,3p)$ ^{14}C cross section and are the only measurements for the $^{nat}Si(p,x)^{14}C$ cross section. New measurements made at the cyclotron at the University of California at Davis for proton energies from 40 Me to 67.5 MeV and at TRIUMF for proton energies from 200 to 450 MeV have extended the energy range over which these cross sections are well known, including the important region near the threshold of the excitation function. In all cases, targets of SiO_2 and Si were irradiated in thin-target conditions that kept the energy loss in a single target to <2 MeV. The total energy lost in the entire target stack for the Davis irradiations was <8 MeV, for the TRIUMF irradiations <1 MeV, and at HCL ranged from <5 MeV at 160 MeV to <10 MeV at 65 MeV. Thus both the secondary neutron production within the target stack and loss of protons due to scattering were minimized. The proton fluence was determined using Faraday cups and the $^{27}Al(p,3p3n)^{22}Na$ reaction measured in Al monitor foils. All the samples were analyzed for ^{14}C at Arizona using well-known methods [3,4].

Details of these measurements and new values of the ^{14}C production cross sections will be presented in the context of their importance to lunar sample and meteoritic studies. These measurements represent the first data available from Si, SiO_2, Al, Mg, and C targets that have already been irradiated at some proton energies. These targets will be analyzed for ^{14}C, ^{10}Be, ^{26}Al, ^{7}Be, ^{22}Na, and the noble gases, while additional relevant target materials will be