deformation history. F1/F2 folds within the zones were inherited from pre D1/D2 deformation and were extensively transposed by D1/D2 deformation. The two sets of high-strain zones may have been conjugated to each other. The strain field of the high-strain zones is unique: lineation plunges almost vertically everywhere. Numerical modeling will be conducted to help understand this conjugation relationship and some special structural feature, e.g. L-tectonite.

BTH 28 Jansyn, Sara M.

OBSERVATIONS ON THE STRUCTURE AND GEOMORPHOLOGY OF THE MINNEWASKA INLIER, MINNEWASKA STATE PARK AND MOHONK PRESERVES, NORTHERN SHAWANGUNK MOUNTAINS, SOUTHEASTERN NEW YORK

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The inlier at Minnewaska formed when an anticline (trending N25E) in the Shawangunk conglomerate (medial to late Silurian) was breached by glacial (Wisconsinan) action exposing slightly deformed late medial Ordovician shales and siltstones of Martinsburg (Bushkill) aspect. Regionally the Shawangunk overlies the Ordovician strata with angular unconformity (Taconic). The contact within the inlier is covered by drift or scree. The inlier is subtriangular with north and west sides bordered by low cliffs. Southeast, the third side is rarely exposed. Overall dimensions are about 6,000 by 3,000 feet (1800 by 900 m). The crest of the asymetric anticline plunges gently to the northeast with subparallel limbs inclined 62° to the southeast and 17° to the northwest. At the latitude of the inlier, the wave length and amplitude of the fold approach 5000 and 300 feet (1500 and 100 m) respectively. Scattered outcrops of Ordovician strata are centered in an area about 3000 by 1000 feet (900 by 300 m). Five exposures projected into a northwest-southeast section suggest an anticlinal and synclinal fold striking north to northeast with limbs rarely inclined greater than 15 degrees. The wave lengths and amplitudes of these folds approximate 1000 and 100 feet (300 and 30 m) respectively. Relief within the inlier is about 320 feet (100 m). Erosion of the Ordovician strata is generally less than 200 stratigraphic feet (60 m). At the bases of most marginal cliffs there is a fringing skirt of large block scree resting on rounded boulder till. Angular blocks of Shawangunk scree seem to have been lowered on a melting stagnant ice surface rather than to have been directly deposited as rock fall. Unlike the rock scour basin at Lake Mohonk and the ice plucked depression at Lake Minnewaska, the Minnewaska inlier is a relatively positive feature within its Shawangunk confines reflecting its original anticlinal morphology.

BTH 29 Waines, Russell H.

THE SOUTHERN EXTENSION OF THE MAJOR POST-TACONIC WALLKILL VALLEY FAULT BETWEEN WALLKILL AND CHESTER, ULSTER AND ORANGE COUNTIES, SOUTHEASTERN NEW YORK

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As previously established, the northern portion of the NNE trending major post Taconic fault in the Wallkill Valley was delineated by imbricated east dipping and younging Ordovician (Martinsburg) shales and siltstones east of the fault and west dipping to overturned, west younging Martinsburg west of the fault. Such relations continue south of Wallkill to the vicinity of Campbell Hall (Orange County) where the fault continues south southwest into an area geologically mapped by T.W. Offield (1967). There the fault was not recognized. East of the fault from Campbell Hall, south to the vicinity of Chester, Martinsburg (Bushkill) strata generally dip and young northwest in the southeast limb of a syncline with an axis near Campbell Hall trending northeast. West of the fault, from Campbell Hall south to the latitude of Goshen, the strata are west dipping to overturned and young west. From Goshen to Chester, beds on the west side of the fault appear to dip and young southeast to the axis of a northeast trending syncline. South from this synclinal axis beds tend to dip and young northwest blending with strata on the east side of the fault. As a consequence, the fault has not been located south of Chester. The synclinal axes on either side of the fault at Chester and Campbell Hall appear to be one and the same with a resultant left lateral offset along the fault trace of about 8 miles (13 km). In addition, left lateral offset of northeast striking Cambro-Ordovician carbonate horses either side of the fault amounts to about 5 miles (8 km). The major fault in the Wallkill Valley is now delineated from the vicinity of Rosendale (Ulster County) to Chester (Orange County) a distance of 32 miles (52 km). The fault appears to transect all prior structures. (Taconic, Acadian?, Alleghanian?) and Ordovician, Silurian and Devonian strata. A possible late Alleghanian displacement is suggested.

BTH 30 Ghosh, Sanghamitra

GEOCHEMISTRY, GEOCHRONOLOGIC AND TECTONIC HISTORY OF THE NICOLA HORST, BRITISH COLUMBIA, CANADA

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The Nicola Horst, in the western part of the Intermontane Belt of British Columbia, Canada, is a mini metamorphic core complex and is separated from surrounding volcaniclastic rocks of the Late Triassic Nicola Group by steep brittle Tertiary normal faults. It includes metavolcanic units correlative with the Nicola Group and quartzite metaconglomerate and graphitic metapelite that are probably older, intruded by mafic and granitic rocks ranging in age from Paleocene to latest Triassic. Supracrustal rocks and early metatonalite are strained, metamorphosed to amphibolite facies and truncated by less deformed plutonic units. The horst provides a 'window' into the middle crust and perhaps below the base of the Nicola Group. The metavolcanics in the horst have more or less similar geochemical trends with the surrounding Nicola Group rocks. Geothermobarometric studies on the metapelites have revealed a pressure – temperature of 3000-4500 bars and 475-500C. Stable oxygen isotope studies have revealed a temperature of 525 C at the southern end of Horst. The upliftment of the horst is tilted with the northern end coming up faster than the southern end and western end coming up faster than the eastern end. The average upliftment rate calculated is 0.21 mm/yr.

BTH 31 Ashcroft, Tristan J.

GEOLOGY AND GEOCHEMISTRY OF THE JONESTOWN VOLCANICS, PENNSYLVANIA

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The Jonestown Volcanic Complex is a 30 km^2 area of igneous rocks located in the Ordovician Hamburg Klippe, a Taconic allochthon. Detailed field mapping of these igneous rocks shows that hypabyssal rocks (diabase) comprise about eighty percent of the areal extent, while basaltic volcanic rocks, including pillows and pillow breccia, comprise only twenty percent, and are restricted to one of the four structural belts of igneous rocks. Field observations show that it is doubtful that there are intact sedimentary or igneous contacts between the igneous rocks and the flysch of the Hamburg Klippe, adjacent to them. The volcanic rocks, however, are locally in original association with massive limestone, the closest regional lithologic analogues of which are Laurentian platform carbonates. The volcanics and associated limestone may be a structural equivalent of the Lebanon Valley sequence to the south, and the limestone resembles the Annville Formation of that sequence. We suggest that the quartzose sandstone capping the Bunker Hills is an outlier of the Silurian Bloomsburg/Tuscarora Formation. Whole rock analysis of trace and rare earth elements shows that the Jonestown igneous rocks are basaltic, and that they are mildly enriched relative to MORB and have sub-alkaline tendencies. Trace element patterns of the hypabyssal rocks can be interpreted to contain hints of continental contamination. Uncertainties in the age of these rocks allow for alternative interpretations of the igneous activity, including a seamount in the Taconic ocean before collision, or on the Laurentian foreland either well before, or during, the arrival of the Taconic subduction system. All possibilities require the igneous rocks to be transported significant distances relative to the flysch. The chemical evidence for crustal involvement and the association of volcanic rocks exclusively with carbonate rocks lacking clastic input suggest a Laurentian foreland interpretation is more likely. The preferred hypothesis, which requires subsequent out of sequence thrusting, is that the igneous activity occurred on the Laurentian foreland just before Taconic collision.

BTH 32 Yates, Jacob

INTRAPLATE TECTONICS: DETERMINING PARAMETERS OF TECTONIC ACTIVITY FROM THE PLATE BOUNDARY TO THE CONTINENTAL CRATON

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A new paradigm is taking shape in understanding intraplate tectonics from a global perspective. The continental craton of the North American plate offers a unique vantage for this type of study. The Canadian Shield along with its outlying geological provinces offers a stable craton for quantifying a baseline of knowledge of minimal tectonic activity. As part of NASA's Solid Earth and Natural Hazards (SE/NH) program, the Global Earthquake Satellite System (GESS) has been proposed to help monitor dynamic crustal motion. However, much of the impetus has been devoted tectonics at well-defined plate boundaries. Tectonics at the intra-plate level would act as an important baseline for quantifying the crustal dynamic range or signal-noise to correlate significant events. Most intraplate studies have focused on localized, infrequent events. Whereas a regional tectonic dataset in a Geographical Information System (GIS) format would provide a synoptic perspective of crustal activity (Yates, et. al, 1999). The thematic layers of each tectonic dataset would contain: 100-year seismic data, macro-scale faulting, focal mechanisms, lineaments, orogenic belts, rifting, regional stress vectors from the World Stress Map (WSM), and Holocene volcanism. This approach has been applied before with the Digital Tectonic Activity Map (DTAM) in quantifying global tectonic activity for the past one million years (Lowman, et. al., 1999). The two plates that our study will include both the North American and Eurasian plates. The approach is as follows: (1) Amalgamate and co-register the tectonic data, (2) Define the spatial scale of the plate boundary region, (3) Determine the transition zone(s) between the plate boundary and craton, and (4) Delineate the intraplate region for study. Once the intraplate region(s) has been defined, we will need to select Areas Of Interest (AOI) for future calibration and validation sites for GESS. Our NASA-funded study is a works-in-progress and we would welcome input of any technique in quantifying intra-plate tectonics.

SESSION NO. 12, 1:05 PM

Monday, March 25, 2002

S3. New Perspectives on the Grenville Orogeny in the United States and Canada: In Honor of Jim McLelland II

Sheraton Springfield, Mahogany

1:05 PM Lowman, Paul D.

TERRANE ACCRETION VS. RE-WORKING: AN EVALUATION BASED ON GEOLOGY OF THE SUDBURY AREA

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Terrane accretion is becoming almost universally accepted as the main mechanism by which continents have been formed. As applied to the Canadian Shield, the concept treats entire crustal provinces, such as the Grenville, as accreted terranes.An older view, however, is that continents have evolved by re-working, largely in situ. The Sudbury area is the junction of three provinces: Superior, Southern, and Grenville. This paper reviews the relationships of these to compare terrane accretion with re-working. Terrane accretion in this area is contradicted by the facts that the Grenville Front is demonstrably not a suture, nor has a suture been clearly identified in the Grenville Province to the southeast. In addition, imbricated Superior-age crust has been radiometrically identified 50 to 100 km southeast of the Front.This implies that the Southern Province was deposited on Archean continental crust, as in fact field relations show. Re-working, in contrast, is demonstrated by radiometrically dated tectonic and magmatic events of the Sudbury area, compiled by D. Rousell et al. Starting with the Levack Gneiss Complex, 2.7 Ga ago, there has been repeated magmatism and tesctonism of crust within an area roughly 150 km on a side for at least 1.7 Ga, down to the Grenvillian Orogeny 1 Ga ago. It is concluded that in this area, crustal evolution has been dominantly a process of repeated reworking of a coherent block of crust, not a series of terrane suturing events.

while some plot on the border of the WPG and the volcanic arc granite (VAG) field on tectonic discrimination diagrams.

Based on data presented here, the Storm King Granite is geochemically similar to mildly A-type granites from Adirondack AMCG suites of roughly the same age (1180-1140 Ma, McLelland et al., 1996) and to A-type granitoids of the Byram Intrusive Suite of the New Jersey Highlands (Volkert et al., 2000). The age, the mild A-type affinity, and the similarity to Adirondack AMCG suites suggests a similar origin by shallow to mid-crustal heating during late- or post-Elzevirian lithospheric delamination and orogenic collapse.

BTH 22 Grover, Timothy W.

METAMORPHIC GEOLOGY OF THE POMFRET DOME AREA, EAST-CENTRAL VERMONT

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The Pomfret Dome is an Acadian, north-trending, approximately 10 km long by 5 km wide antiformal structure within the Connecticut Valley-Gaspe Synclinorium in east-central Vermont. The dome is comprised of the Waits River (calcareous and metapelitic rocks), Standing Pond (mafic gneiss and amphibolite ± garnet), and Gile Mountain (metapelitic schist, quartzite) Formations.

Mineral assemblages in metapelitic rocks indicate a range in metamorphic grade from garnet zone around the periphery of the dome, through staurolite, staurolite + kyanite, to kyanite zone rocks in the core of the dome, with the local development of sillimanite zone assemblages. Geothermobarometric calculations for staurolite + kyanite and kyanite zone rocks suggest peak metamorphic conditions were approximately 600 °C and 7-8 kbar. Curved inclusion trails and discontinuities in inclusion trail patterns in garnet suggest syn-deformational garnet growth. Curved inclusion trails also occur in deformed staurolite and kyanite. This texture implies that deformation continued after growth of these porphyroblasts. Late stage chlorite and muscovite crosscut the crenulated foliation.

Garnets in the metapelitic rocks are almandine-rich and compositional profiles show decreasing spessartine contents and Fe/Mg ratios from cores to rims, features typically associated with growth zoning. X-ray maps reveal garnet compositions were modified along rims, mineral inclusion boundaries, and fractures. There is a marked decrease in grossular content of garnet with a concomitant increase in the pyrope and almandine components in these regions. However, there is little to no change in the ratio of the almandine/pyrope components. In some, but not all samples, the compositional discontinuity is accompanied by the presence of abundant fluid inclusions in the garnet, both along the garnet rim and in the garnet interior near mineral inclusion contacts. These observations suggest high-temperature interaction between garnet and fluid.

BTH 23 Lupulescu, Marian V.

MINERALOGY AND GEOCHEMISTRY OF SOME BASE METAL OCCURRENCES IN THE CENTRAL TACONIC REGION (NEW YORK)

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Our study focuses on the base metal occurrences (Pb-Zn; Cu-Pb-Zn) in the central part of the Taconic region. They form narrow veins and impregnations in the Ordovician dolostones and calcschists. The optical mineralogical study revealed the following mineralogical record: galena, sphalerite, pyrite, tetrahedrite-tennantite, chalcopyrite and native gold with smithsonite, hemimorphite, aurichalcite, malachite, azurite, and anglesite as secondary minerals usually exhibiting replacement textures. The trace element composition of the sulfides showed high Ag content 257 ppm to 766 ppm (tetrahedrite-tennantite), Cd 4345 ppm to 5452 ppm (sphalerite), In 105 ppm (sphalerite), Ni 1844 ppm, Co 311 ppm, and As 122 ppm (pyrite). Se displays a homogeneous content for all the analyzed sulfides (2 ppm to 19 ppm). The Pb composition of galena is less radiogenic (206Pb/204Pb is 18.566-18.944) than in the Mississippi Valley type ores (J-type lead). The homogeneous Pb isotopic character, the similarity between Pb isotopic composition of these ores and Shawangunk Mountains base metal ores make us consider either a single source of the Pb or fluids from multiple sources that were mixed before galena precipitated. We could consider a possible common origin for the galenas hosted by the two units. A similarity with the other Appalachian ores is also indicated. The sulfur isotopes display a narrow range for individual mineral species (delta 34S is between 3.3 and –4.1). These values are close to those of the pyrite from the base of the Shawangunk Formation overlying the Taconic unconformity, but very different from the sulfur composition of the Shawangunk sulfides implying a different origin. A progressive decrease of the delta 34S for the sequence pyrite-sphalerite-galena is possibly related to the normal trend during the equilibrium fractionation. The low delta 34S could represent the result of the bacterial reduction of sulfur derived from an underlying unit.

BTH 24 Englander, Leah

GEOCHEMICAL AFFINITIES OF INTERMEDIATE AND MAFIC LAYERS IN METAMORPHOSED LATE PROTEROZOIC SEDIMENTARY AND RHYOLITIC STRATA, PELHAM DOME, MASSACHUSETTS

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In the late 1960's Robinson and D. D. Ashenden collected samples during construction of the Northfield Mtn. Pumped Storage Hydroelectric Project. One sample set was of metamorphosed mafic and intermediate igneous rocks, mostly hornblende-rich boudins, from Late Proterozoic strata deepest in the core of the Pelham gneiss dome. Most samples are from Poplar Mountain Quartzite and stratigraphically overlying Poplar Mountain Gneiss of sedimentary derivation. A few are from underlying Dry Hill Gneiss having the right chemistry and interpreted as metamorphosed alkali rhyolite (Hodgkins 1985), and yielding an igneous U-Pb zircon age (Tucker & Robinson 1991) of 613 ±3 Ma (Vendian). These mafic rocks appear to have been emplaced penecontemporaneously with the Dry Hill Gneiss and are conspicuously different from mafic rocks in the overlying Late Ordovician Fourmile Gneiss (Bull 1996). These were metamorphosed one or more times to high grade with partial melting of gneisses and pegmatite emplacement. They have reasonably coherent igneous characteristics for immobile elements, but alkali and alkaline earth metals have, not surprisingly, undergone substantial redistribution. Preliminary data on 22 analyzed samples show 7 are intermediate rocks, 13 are mafic resembling basalts, and two are ultramafic rocks, apparently contaminated pyroxene-rich cumulates. The mafic rocks are all high in TiO_2 (up to 4%), high in Nb (up to 111 ppm), and LREE-enriched. In western New England, rocks most closely resembling these are the Eo-Cambrian Tibbit Hill Formation (Coish 1985), interpreted as volcanics associated with rifting of the Laurentian margin, though Nb concentrations are higher in some Northfield samples. We interpret most mafic samples to have been basalts derived from enriched mantle, emplaced as dikes or flows during a Late Proterozoic rifting event. The plate setting was most likely on a peri-Gondwanan margin of Iapetus, though the Laurentian margin cannot yet be excluded. Work is proceeding to complete the data sets and expand comparisons with data sets of known provenance.

SESSION NO. 11, 1:00 PM

Monday, March 25, 2002

Structural and Tectonic Analysis (Posters)

Sheraton Springfield, Ballroom North

BTH 25 Schoenborn, William A.

CONDITIONS OF DEFORMATION IN THE MATHER GORGE AND SYKESVILLE FORMATIONS, POTOMAC RIVER, SW MARYLAND AND N VIRGINIA

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Current models of deformation in the central Appalachian Piedmont postulate that lithologies of the Mather Gorge Fm. were polydeformed prior to deposition of the Sykesville Fm. (Drake and Froelich, 1997). New structural analysis of Piedmont rock units exposed along the Potomac River SE of Great Falls, Md. confirms that the Mather Gorge and Sykesville Fms. exhibit a complex polygenetic history and provides evidence that both units experienced the same deformation events. Early recumbant tight isoclinal folds (F_a of Schoenborn, 2001) that are well developed in Mather Gorge metapelites are also observed in a sample of Sykesville (interlaminated muscvt schist - qtz-fsp granofels) collected from a construction site close to the Potomac River. Qtz c-axis pole figure patterns developed from 6 samples of Mather Gorge and Sykesville tectonites collected along the river exhibit an orthorhombic symmetry, a symmetrical broad small circle distribution about Z, and a lack of maxima parallel to Y, which are interpreted to be the result of predominantly coaxial non-rotational flattening strain related to later upright parallel folds (F_b). 2-D strain measurements from 51 elliptical markers in the Sykesville (biotite clasts within qtz fsp granofels) using the Rf/ϕ' technique suggest a bulk finite strain of 7.0 which is consistent with 2-D strains measured from lithologies in the Mather Gorge Fm. Within the phyllonitic rocks of the Mather Gorge, cm-scale pods of qtz-fsp leucosome (former cumulate melt) between pulled-apart host rock, and metric-scale tabular bodies of dark banded agmatitic rock (sheared diatexite) suggest that initial shearing of the phyllonitic rocks occurred under high temperature near solidus conditions. F_b axial planes in phyllonitic schist are defined in thin section by smooth zonal mica cleavage domains that anastomose around lenticular qtz-muscvt-chlrt microlithons, which preserve older S_a cleavage at high angle to dominant S_b foliation. Discreet transition from cleavage domains to microlithons is commonly marked by dusty trains of opaque minerals and suggests pressure solution mechanisms operated during F_b folding. Greenschist mineralogy, meso- and microscopic textures, and broad small girdle patterns in quartz c-axis pole figures (30 deg. small circles), are consistent with late strain at lower temperatures.

BTH 26 Carter, Brooke L.

KINEMATIC ANALYSIS OF THE GARTH RUN SHEAR ZONE IN THE BLUE RIDGE PROVINCE OF VIRGINIA

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Ductile shear zones are commonly developed in the Appalachian mountain belts. In the Canadian Appalachians (Newfoundland, Nova Scotia), a lot of these shear zones exhibit strain geometries suggesting triclinic transpressional deformation paths. We have investigated a well-exposed ductile shear zone in the Blue Ridge province of Virginia, the Garth Run shear zone, in order to reveal its kinematic history. The Garth Run shear zone is developed in the Livingston Group consisting of leucogranite, charnokinte, metabasalt and pegmatites. The shear zone strikes nearly north-south and dips east at about 40 degrees. Mylonitic C-foliation is well developed throughout the zone, and there is a compositional layering parallel to the C-foliation defined by transposed and boudinaged pegmatite layers, flattened pegmatite boudins with tails, and flattened metabasalt. There is a down-dip stretching lineation on the mylonitic C-foliation. Fabric asymmetry is observed both on the section parallel to the lineation and perpendicular to the C-foliation (down-dip section) and perpendicular to the stretching lineation (along-strike section), producing a triclinic symmetry. On the down-dip section, the asymmetry is defined by an S-C fabric indicating a top to west thrusting sense of shear, while on the along-strike section the asymmetry is defined by pegmatite boudins with tails suggesting a sinistral sense of shear. A C'-foliation is visible on the along-strike section, but the sense of shear varies between samples along strike of the zone. It is possible the sinistral shear is an overprinting on the thrusting sense of shear. We thus conclude that the Garth Run shear zone has a thrusting-dominated sense of movement overprinted by a sense of movement with more sinistral strike-slip component. Whether the earlier thrusting-dominated sense of movement has a significant strike-slip component and therefore has produced a triclinic fabric in the mylonite is being investigated by microstructural analysis. We also propose a tectonic model for the kinematic history of the Garth Run shear zone.

BTH 27 Dai, Tianhuan

KINEMATICS AND DEFORMATION HISTORY OF THE CENTRAL CROSS LAKE SHEAR ZONE

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The tectonic environment in which Archaean greenstone belts have developed is of paramount importance to understand early Earth evolution. One effective way to unravel tectonics is to study the strain geometry and kinematics from geological structures preserved in the belts and then to examine likely tectonic environments that might produce the structural pattern. The Cross Lake greenstone belt in the northwestern Superior structural province, Canada, is characterized by two sets of high-strain zones, trending ~NE 060 and WNW – ESE respectively. On the basis of previous mapping and work on geochronology and metamorphism, we have conducted structural analysis of the Cross Lake greenstone belt, concentrating on the ESE-trending high-strain zone, the Central Cross Lake Shear Zone (CCLSZ). Five generations of deformation have been identified within the CCLSZ. D1/D2 deformation is defined by isoclinal folds, which are intrafolial to a dominant transposition foliation. D3 are generally open to tight asymmetrical folds overprinting the transposition foliation. Both D1/D2 and D3 have a dextral sense of movement, and are interpreted as a continuous progressive deformation. D4 is defined by en echélon veins observed in amphibolites or other competent layers. The veins indicate a sinistral sense of movement. D5 produces open to tight asymmetric folds indicating a dextral sense of movement. Three generations of folds are observed outside of the high-strain zones with variable styles and orientations. Combined with the structural analysis of the NE-trending zone, we suggest that the F1/F2 folds within the zones and outside the zones may have shared the same early

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