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RELATIONS BETWEEN EXTENSIONAL TECTONICS AND MAGMATISM WITHIN THE SOUTHERN OKLAHOMA AULACOGEN

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Variations in the geometry, distribution and thickness of Cambrian igneous and sedimentary units within southwest Oklahoma are related to a late Proterozoic - early Paleozoic rifting event which formed the Southern Oklahoma aulacogen. These rock units are exposed in the Wichita Mountains, southwest Oklahoma, located on the northern margin of a Proterozoic basin, identified in the subsurface by COCORP reflection data [1]. Overprinting of the Cambrian extensional event by Pennsylvanian tectonism obscured the influence of pre-existing basement structures and contrasting basement lithologies upon the initial development of the aulacogen.

Gilbert [2] identified the beginning of the rifting stage as the rise of a basaltic liquid which formed the intrusive Glen Mountain layered complex (GMLC), with an extrusive equivalent, the Navajoe Mountain basalt-spilite group (NMBS) (Fig. 1b). This was probably accompanied by brittle faulting which accomodated extension in the upper crust (not shown in Fig. 1). The greater than 4 km thick GMLC [3] was intruded at shallow depths and must have resulted in extensive updoming of the overlying basement rocks of the Proterozoic basin margin. Thermal expansion must have added to the doming component, perhaps exposing the gabbros to erosion. The GMLC consists dominantly of heteradcumulate/adcumulate anorthositic layers. Abundant strongly laminated plagioclase layers indicate a high degree of compaction which may reflect seismicity (faulting) contemporaneous with consolidation. The associated NMBS formed uniformly thick (300 m) flows across the area [4].

Faulting of the area (now in the general vicinity of the Pennsylvanian Frontal Fault Zone) on arcuate, concave-upward, normal faults, resulted in rotation of the gabbro layering to a north dip as rifting initiated within the aulacogen (Fig. 1c). Dips estimated from mineralogical layering within compositional zones in the GMLC, and from the attitude of the zones themselves, are presently about 10 degrees to the north. Cambrian tilting would have been at higher angles but would have been rotated back during Pennsylvanian compression. Igneous activity was confined to the aulacogen and resulted in a relatively higher heat flow than on the surrounding craton. This suggests that extension occurred along low-angle normal faults analogous to those described for Cenozoic crustal thinning in the Basin and Range province [5]. Post-extensional isostatic re-equilibration resulted in further erosion of the gabbro body and overlying country rock (Fig. 1d). The latter may have provided the source for the Meers metaquartzite which was then deposited locally in fault block sub-basins.

A layering discordance is observed between the GMLC and later Roosevelt gabbros [2] which show a less well defined mineralogic layering, also dipping to the northeast. Therefore, block faulting must have rotated the host GMLC before intrusion of the Roosevelt Gabbros. A Cambrian age is inferred for faulting which truncated the Proterozoic basin layering to the south [1]. In addition, faulting is also documented to have taken place along strike, to the southeast, at this time [4]. Faulting continued during the unroofing erosional event of the two gabbro units because both show layering discordance with overlying granite/rhyolite.

Rhyolite was extruded onto the eroded gabbro unconformity during middle Cambrian. At the southeast end of the aulacogen the rhyolite is 1500 m thick to the northeast and absent to the southwest, indicating that it was laid down in a half graben [4]. North of the Wichita Mountains the Carlton rhyolite is known to be more than 1300 m thick, ranging up to 4000 m in places, but it is unknown to the south of the area. Consequently, a similar half graben structure is postulated for the Wichitas, rather than a later tilting and erosional event such as that suggested earlier [4].

Eruption of the rhyolite may also have been strongly fault controlled. Mapping of ash-flow eruptions elsewhere has shown them to be circular caldera structures overlying pendant-shaped silicic plutons. No caldera structures have been identified in the exposed Wichita Mountains. The lack of distinct gravity lows in the otherwise prominent positive Bouguer gravity confirm that subcaldera structures are missing. Therefore, the rhyolites must have been erupted along linear fissures, perhaps the normal faults themselves.

Within the Wichita Mountains, rhyolite is present overlying GMLC but it has not been shown to be as thick as to the northeast. This may be a consequence of erosion associated with Pennsylvanian uplift, however, the conglomerates derived solely from this erosion have a granitic source [6]. Alternatively, the intrusion of the Roosevelt gabbros may have stabilized the central Wichita 'block' sufficiently to lessen its subsequent rotation and subsidence. The largest volume of rhyolites was, therefore, laid down in rapidly subsiding fault basins north of the central block (Fig. 1e). COCORP evidence suggests that the rhyolites spread beyond the bounding faults of the aulacogen onto the cratonic platform [1, p. 111]. In the Arbuckle Mountains, to the southeast, no major basic intrusives are observed and the rhyolites are contained within the boundaries of the faulted region.

The rhyolite-gabbro contact on the stable central block was favored for the intrusion of the Wichita Granite Group as relatively thin (500 m), but laterally extensive, sills. The granites crystallized from a dry, high temperature (900°-1000°C+) magma which rose near its liquidus. Bulk compositions plot on or near the 4 kb dry boundary curve in the system Qtz-Ab-Or suggesting derivation from a source about 10-15 km deep. This implies rather large mafic plutons at intermediate depths in the crustal column as well as feldspathic-rich "continental" layers available for partial melting. The thermal pulse related to the granite/rhyolite formation would have been strong enough to have potentially generated geothermal gradients of 60-80°C/km within the aulacogen proper. The Meers metaquartzite shows variable metamorphism from low-grade involving chlorite/green-white micas through rare andalusite-bearing rocks to prevalent sillimanite-cordieritespinel grade. These had previously been thought due to contact metamorphism but may additionally reflect a more regional event of the higher postulated heat flows.

Because the granite/rhyolite source is thought to have been at about 10-15 km, and because the rhyolites may have erupted from the faults, it is possible that the listric basal zone for the extensional faults was the zone of partial melting itself. This zone would have directly overlain the gabbroic mass responsible for the melting and which later acted as a source for diabase dikes.

The last igneous activity was a set of late diabase dikes which show trace element patterns of two interrelated types: 1) a monotonic pattern characteristic of primary continental tholeiites and 2) a modified monotonic pattern with small positive Eu anomalies. The latter set must have tapped crystallizing basaltic magma chambers in the crust. Presumably these are the ones providing the heat necessary to produce the silicic melts at 10-15 km depths.

Igneous activity ceased before the onset of deposition in the late Cambrian, as diabase dikes do not cut the Reagan sandstone at the base of the sedimentary section. This is consistent with a high level crustal heating which could then decay relatively rapidly. Normal gradients must have been obtained, and thus relative cooling, so that basin subsidence could begin.

The aulacogen trend influenced deposition in southern Oklahoma and northern Texas during the lower Paleozoic as the isopach map of the Arbuckle group (Upper Cambrian-Lower Ordovician) shows thinning from the aulacogen, to the southwest (Denison, 1984, personal communication). This thinning can not be explained by erosion along Pennsylvanian structures aligned east-west (Matador Arch, Red River Arch). It is suggested that the thinning occurs across a peripheral bulge which formed a positive feature adjacent to the aulacogen during the Lower Paleozoic. This is consistent with thermal models of basin evolution [7]. Within southern Oklahoma the axis of maximum deposition migrated northward, parallel to the aulacogen trend, during the Paleozoic [8, 9].

Pennsylvanian tectonism uplifted the igneous rocks to the surface along 30-40 degree reverse faults [1]. Prior to uplift these rocks would have been in the brittle field of deformation. As these rock types would have high ultimate strengths in compression it is suggested that they failed preferentially along suitably oriented pre-existing lines of weakness. Consequently, the faults delineated by COCORP [1] may represent reactivated Cambrian normal faults. Rotation along these faults would have been in the opposite sense during the Pennsylvanian, than in the Cambrian, causing shallowing of the original dips and rotating the granite sill until it dipped gently to the southwest in some places.

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FIGURE CAPTION

Figure 1. Development of the Southern Oklahoma aulacogen.

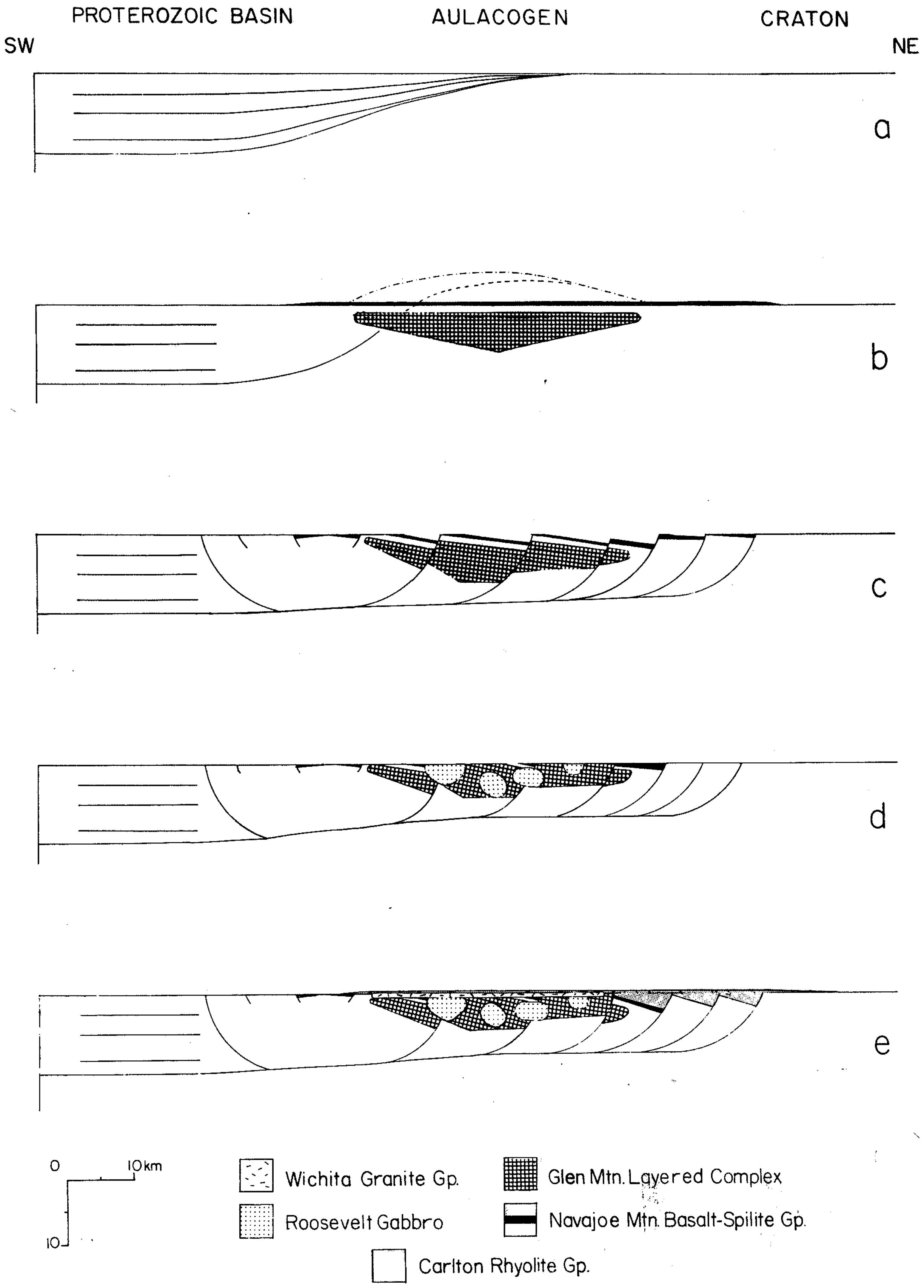
a. Postulated pre-aulacogen basement configuration;

b. initial extension accompanying intrusion of GMLC and extrusion of NMBS is masked by physical and thermal doming;

c. continued extension results in faulting and rotation of igneous units;

d. isostatic re-equilibration, intrusion and rotation of Roosevelt gabbros;

e. continued extension results in extrusive rhyolites accumulation northeast of central, stabilized Wichita block; granite sill intrudes along rhyolite/gabbro contact.


PROTEROZOIC BASIN
AULACOGEN
CRATON
SW
NE
a
b
c
d
e
0
10km
10
Wichita Granite Gp.
Roosevelt Gabbro
Glen Mtn. Layered Complex
Navajoe Mtn. Basalt-Spilite Gp.
Carlton Rhyolite Gp.