مرز جنوبی خشکی لورآسیا در شمال خاوری ایران

نوشتهٔ: دکتر ا. و. روتنر

تهیه خلاصه نوشتار به فارسی توسط : مهندس مصطفی شهرابی

خلاصه نوشتار:

گستره‌ای که از دیر باز به عنوان مرز جنوبی خشکی لورآسیا (توران) و خرده قاره ایران مرکزی مورد گفتگو بوده، در خاور و جنوب خاوری شهر مشهد قرار دارد که Stocklin (1977) آن را مرز بین حوزه رسوبی مرکزی و حوزهٔرسوبی شمالی و Cengor (1990) آن را مرز بین دو حوزه رسوبی سیمرین و لورآسیا نامیده است.
متأسفانه برون زد سنگ‌هایی در پی‌سنگ پیش از ژوراسیک فقط در دو منطقه زیر دیده شده است:

۱- به سمت شمال درفرونشست تربت جام- فریمان

۲- پنجره فرسایشی آق‌دربند در بخش خاوری رشته کوه‌های کپه‌داغ

که منطقه اولی توسط Eftekhar Nezhad and Behroozi (1991) و دومی (پنجره فرسایشی) توسط Baud and Brander در سال‌های ۱۹۷۲ و ۱۹۷۷ مورد بازدید و بررسی قرار گرفته است. نویسنده نیز در سال‌های ۱۹۷۵ و ۱۹۷۶ به منظور تهیه نقشه زمین‌شناسی معدن ذغال سنگ آق‌دربند همراه تعدادی کارشناس منطقه را مورد بررسی‌های دقیق قرار داده که نتایج آن به چاپ رسیده است (Ruttner 1991).

در نوشتار مزبور کلیهٔنتایجی که در رابطه با مسایل ژئودینامیکی منطقه از دیدگاه نویسنده حاصل شده بود، با زمین‌شناسان مختلف به بحث و تبادل نظر گذارده شد. در این گفتگوها افرادی مانند Belov (1986)، Boulin (1988)، Cengor (1985, 1986,1990) و Stocklin (1977, 1984) شرکت داشته‌اند که نتایج به دست آمده مورد توافق همگان نبوده است. نظر نویسنده مقاله در این مورد به شرح زیر است:

دانسته‌های زمین‌شناسی

افیولیت‌های زمان پرمین مشهد- فریمان

وجود سنگ‌های افیولیتی شامل دونیت، ورلیت، سرپانتینیت غنی از آنتی گوریت، گابرو پیروکسن‌دار و بازالت دگرگون شده همراه با لایه‌های نازک از رادیولاریت از خاور و شمال خاوری مشهد توسط مجیدی و علوی تهرانی (۱۹۷۱) و Majidi (1978) گزارش شده که به وسیله Diefenbach et al (1978) نیز با مشخص نمودن لایه‌های مرمری به عنوان قاعده این سری، تایید شده است. این توالی سنگ‌ها تصور می‌شد که متعلق به زمان دونین- کربنیفر (Majidi 1978) و یا باقی‌مانده‌ای از پالئوتتیس (Diefenbach et al. 1986) باشد.

Eftekhar Nezhad and Behroozi (1991) ادامه جنوب خاوری افیولیت‌های مشهد را در منطقه فریمان- تربت جام در طول ۱۵۰ کیلومتر ردیابی نمودند در این زون که درجه دگرگونی از مشهد به طرف جنوب خاوری کم

می‌شود واحد سنگی را به شرح زیر تشخیص داده‌اند:

– واحد زیرین– از توربیدیت‌های دانه‌ریز و رادیولاریت و چرت همراه با روانه‌های بالشی و سنگ‌های فوق بازیک تشکیل گردیده است. در نمونه‌ای از سنگ‌های آهکی پلاژیک خاور روستای سنگ سفید فسیل‌هایی یافت شده‌اند که سن پرمین‌زیرین (کونگورین پسین) را مشخص نموده‌اند (Kozur and Mostler 1991). همراه با آهک‌های پلاژیک ستبرای زیادی از سنگ‌های رسوبی نهشته شده در ژرفای کم وجود دارد که بزرگ‌نیا (۱۹۹۱) سن پرمین زیرین تا میانی (اسیلین– ساکمارین تا ساکمارین– مرگابین) را به این واحد داده است.

– واحد بالایی – از سنگ‌های آواری ریزدانه، فیلیت و شیل همراه با میان‌لایه‌هایی از آهک‌های متبلور شده و اسلیت تشکیل شده که در آن هیچ‌گونه شاهد فسیلی وجود ندارد. برای این واحد سن پرمین بالا– تریاس زیرین در نظر گرفته شده است (Eftekhar Nezhad and Behroozi 1991). به سوی شمال خاوری فریمان این افیولیت به وسیله سازند کشف‌رود و با واسطه دگرشیبی زاویه‌دار پوشیده می‌شوند.

پنجره فرسایشی آق دربند

چهل کیلومتر دورتر (در شمال خاوری فریمان) پنجره فرسایشی آق‌دربند پی‌سنگ قبل از ژوراسیک را در جنوب خاوری رشته کوه‌های کپه‌داغ به نمایش گذاشته است.

در این پنجره فرسایشی ساختارهای قبل از سیمرین که در اثر دگرشکلی‌های بعدی تغییر نکرده‌اند، باقی‌مانده‌اند به این معنی که بخش کوچکی از ساختارهای مربوط به قبل از سیمرین لور آسیا در منتهی‌الیه جنوبی آن در آق‌دربند دیده می‌شود که حدود ۵۰×۱۵ km وسعت دارد.

این پنجره فرسایشی از مدت‌ها قبل (Goldschmidt 1956) شناخته شده است. قسمت جنوبی آن در سال‌های ۱۹۷۵ و ۱۹۷۶ توسط روتنر بررسی و در سال ۱۹۹۱ نتایج آنها منتشر گردید. (Eftekhar Nazhad and Behroozi (1991) پس از تهیه نقشه چهارگوش تربت جام نتایج آن را به نگارش درآورده‌اند. این پنجره فرسایشی دارای ویژگی‌های زیر است:

۱– توالی سنگ‌های دیرینه‌زیستی شامل سنگ‌های رسوبی، آذرین، همراه با میان‌لایه‌هایی از آهک‌های مربوط به زمان فرازنین– فامنین. بخش بالایی دونین در این توالی تشابه فراوانی با سویت Kartzhurskaya در کوه‌های

قفقاز دارد (Belov et al 1978) که مسئله پی‌سنگ بودن آن را برای کوه‌های کپه‌داغ تایید می‌کند.

۲- ترياس آق‌دربند از مجموعه‌ای از سنگ‌های آواری (شیل، ماسه‌سنگ، کنگلومرا) قرمز رنگ، دریایی با ژرفای کم و تناوبی از آهک‌های گرهک‌دار، شیل، ماسه‌سنگ، کنگلومرای یک زادی (Monomictic)، توربیدیت‌های آذرآواری، همراه با لایه‌هایی از ذغال‌سنگ برجای (Autochtoneous)، تشکیل شده که مجموعاً ۱۰ بخش (a تا l) را تشکیل داده‌اند که زیر پوشش دگرشیبی سازند کشف‌رود قرار می‌گیرند.

۳- یک زون تکتونیکی از نوع فلس ماهی‌یی (Schuppen Zone) در بخش جنوبی این پنجره وجود دارد که از اسلیت‌های قرمز و سبزرنگ، کمی دگرگون شده و ماسه‌سنگ‌های سخت که به گمان بخش زیرین پی‌سنگ ملاسی هرسینین می‌باشد، تشکیل سنگ‌های دگرگون نشده ترياس مخلوط شده را داده است. این زون تکتونیکی به وسیله یک گسله اصلی (گسله شاه توتک) که در امتداد آن پی‌سنگ آذرآواری‌های دونین برونزد دارند، قطع شده است.

٤- در منطقه وسیعی نهشته‌هایی از شیل‌های قرمز رنگ همراه با ماسه‌سنگ و کنگلومرا مربوط به زمان اسکیتین زیرین (سازند قره قیطان) وجود دارند که در قلوه‌های آهکی آنها فسیل‌های مربوط به کربنیفر و در یک مورد پرمین زیرین یافت شده که زیرسازند سفیدکوه قرار دارد. وجود این سنگ‌ها در زیر سازند مزبور سن اسکیتین زیرین را برای آن تایید نموده است. یک لایه کنگلومرایی که در آن قلوه‌های رادیولاریت و سنگ‌های افیولیتی دیده شده با دگرشیبی روی افیولیت‌ها قرار دارند.

۵- افیولیت‌های دره انجیر که در گوشه جنوب باختری این پنجره یافت شده‌اند، اغلب از نوع آمیزه رنگین همراه با سنگ‌هایی از نوع توف‌های دیابازی، رادیولاریت و چرت‌های رادیولاریت‌دار، سنگ‌های فوق بازیک، شیل‌های فیلیتی و کمی آهک می‌باشند که در آهک‌های این آمیزه خرد فسیل‌های پرمین پسین دیده شده است (کشانی و بزرگ نیا در نوشتار مربوط به افتخارنژاد و بهروزی ۱۹۹۱).

ساختار

ساختار پیش از رخداد سیمرین در پنجره فرسایشی آق‌دربند برونزد کامل دارد. این پنجره فرسایشی با فشار مایلی که از جنوب باختری و به وسیله گسلش راستالغز از گونه چپ گرد حاصل شده به وجود آمده است.

لایه‌های ترياس در بین گسله‌های راستالغز چپ گرد (گسله اصلی شمالی) فشرده شده‌اند که مرز این لایه‌ها را در مجاورت با پالئوزوئیک مشخص می‌سازد و یک گسله رورانده (گسله اصلی جنوبی) سبب شده که زون فلس ماهی‌یی روی لایه‌های ترياس رانده شود.

ساختار داخلی سنگ‌های ترياس یک ناودیس کم و بیش گسترده‌ای است که در قسمت باختری همراه با یک تاقدیس می‌باشد. اسه این چین ۲۰ تا ۳۰ درجه کج‌شدگی به سوی خاور جنوب خاوری دارد. یک ناودیس مرکب که از سه یا چهار ناودیس باریک تشکیل شده با واسطه یک گسله راندگی در بخش خاوری دیده می‌شود.

تعداد بی‌شماری از چین‌های کوچک در ماسه‌سنگ‌های آتش فشان‌زاد و سازند سینا نزدیک به گسله اصلی شمالی وجود دارد که اسه‌های آنها چرخشی در جهت حرکت عقربه‌های ساعت را نشان می‌دهند که دلیلی بر وجود یک گسله چپ‌گرد در امتداد آن می‌باشد (Ruttner 1991).

زون فلس ماهی‌یی در بخش جنوبی از تعدادی تکه‌های رانده شده که زیرین‌ترین آن دارای لایه‌های دگرگون نشده ترياس است تشکیل شده است.

گسله اصلی دیگری بنام گسله شاه‌توتک وجود دارد که زون فلس ماهی‌یی را از طرف جنوب باختری قطع می‌نماید. این گسله نیز به گمان یک گسله راستالغز بوده که برنهشته‌های ژوراسیک اثر نموده است.

Eftekhar Nezhad and Behroozi (1991) اشاره به دگرشکلی افیولیت‌های قبل از سیمرین در ناحیه مشهد- فریمان نموده‌اند. آنها براین گمان‌اند که نفوذ گرانیت مشهد همزمان با دگرگونی از نوع دینامومتامرفسیم از پی‌آمدهای رخداد تکتونیکی سیمرین پیشین است.

سنگ‌های خرده قاره ایران مرکزی در حدود ۲۰ تا ۳۰ کیلومتری جنوب باختری کمربند افیولیتی پرمین این منطقه در یال جنوبی کوه‌های بینالود (جنوب خاوری مشهد) یافت شده‌اند که هم‌ارز سازندهای پادها، سیب‌زار و بهرام منطقه ازبک کوه- شیرگشت (شمال طبس) می‌باشند و به صورت تکه‌های تکتونیکی بین فیلیت‌های مشهد دیده می‌شوند (Lammerer et al. 1983). نظیر همین سازندها همراه با سازند شتری در جنوب باختری تربت جام نیز دیده می‌شود.

مفاهیم ژئودینامیکی

براساس مدل‌های ژئودینامیکی موجود، اقیانوس پالئوزوئیک (پالئوتیس) بین لور آسیا (ورق توران) و خرده ورق ایران مرکزی (سیمریا) در زمان تریاس در اثر برخورد دو ورق بسته شده‌اند این برخورد سبب دگرشکلی سیمرین پیشین شده است. بررسی‌های انجام شده در گوشه شمال خاوری ایران وجود گودال اقیانوسی پرمین را بین دو خشکی تایید نموده است.

این گودال چنین نشان می‌دهد که تا تریاس زیرین بیش‌تر ادامه نداشته است. در نتیجه می‌توان گفت ساختار سیمرین پیشین در پنجره فرسایشی آق‌دربند نتیجه بلافاصله برخورد دو قاره نبوده است.

لبه جنوبی خشکی لور آسیا به وسیله گسلش راستالغز چپ گرد سیمرین پیشین و فشار مایل کنترل می‌شده است.

دریای تریاس آق‌دربند در حوزه کششی بین قاره‌ای تشکیل شده که در آن رسوب‌گذاری و دگرشکلی در نورین پسین و رتین پیشین پایان یافته است. گسلش راستالغز چپ‌گردی بین لبه جنوبی اوراسیا و کمربند افیولیتی پرمین نیز صورت گرفته که بهرحال سبب شده افیولیت‌های پرمین و خشکی لور آسیا به طور محلی بعد از تریاس با هم در ارتباط باشند. این امر با وجود پوشش سنگ‌های ژوراسیک- کرتاسه که کم تغییر یافته‌اند مشخص است.

با توجه به ارتباط تریاس ایران مرکزی و لور آسیا، می‌توان به نتیجه کار Davoudzadeh et al.(1981) اشاره نمود. برپایه بررسی‌های زمین‌شناسی و دیرینه مغناطیس آن‌ها به این نتیجه رسیده‌اند که خرده ورق ایران مرکزی- خاورایران در زمان تریاس چرخشی معادل ۱۳۵ درجه در جهت خلاف حرکت عقربه‌های ساعت داشته است که در حال حاضر این انگاره به میزان زیادی مورد قبول واقع شده است.

یک چرخش دوباره خرده قاره ایران مرکزی نسبت به موقعیت پیشنهادی بالا سبب جابگزینی تریاس نخلک (و دگرگونه‌های انارک) شده که در حال حاضر می‌توان آن را از نائین (خاور ایران مرکزی) به سوی آق‌دربند دید چگونگی وجود توالی سنگی این دو تریاس مدت‌ها مورد گفتگوی زمین‌شناسان بود به ویژه وجود Nicomedites به عنوان فسیل مهم زمان آنیزین پیشین در دو منطقه به اثبات رسیده است.

Davoudzadeh et al. (1981) بیان نموده‌اند که خرده قاره ایران مرکزی در زمانی بین تریاس و پرمین چرخش دیگری معادل ۴۰ درجه در جهت حرکت عقربه‌های ساعت داشته که سبب حرکت آن به طرف مدار ۲۷ درجه شمال شده است که این مدار در واقع همان مرز جنوبی اوراسیا در تریاس بوده است، و به این ترتیب می‌تواند بر برخورد اوراسیا با ایران مرکزی در تریاس زیرین دلالت نماید بین تریاس و ژوراسیک زیرین جهت حرکت و چرخش ایران مرکزی تغییر نموده است. چرخش در جهت خلاف عقربه‌های ساعت که از تریاس آغاز گردیده بود در ترسیر زیرین و میانی پایان یافته است.

برخورد خرده قاره ایران مرکزی و اوراسیا در تریاس پیشین و چرخش درجهت عقربه‌های ساعت این خرده قاره بین پرمین و تریاس در بررسی‌های دیرینه مغناطیسی در سال ۱۹۸۱ به اثبات رسیده که تا آن زمان ناشناخته بود.

حال پس از گذشت ۱۰ سال شواهد زمین‌شناسی موجود در آق‌دربند و فریمان این موضوع را ثابت می‌نماید که:

– یک گودال اقیانوسی که لورآسیا و ایران مرکزی را از هم جدا می‌نموده در زمان پرمین وجود داشته است. ولی این گودال تا تریاس بیش‌تر دوام نداشته است.

– یک چرخش در جهت عقربه‌های ساعت در خرده قاره ایران مرکزی سبب بوجود آمدن دگرشکلی سیمرین پیشین در لبه جنوبی اوراسیا شده باین معنی که گسلش راستالغز چپ‌گرد و فشار مایل سبب چین‌خوردگی و روراندگی‌ها و جدایش خشکی‌ها از یکدیگر و پرشدن از رسوبات تریاس شده‌اند.

– براساس تعبیر و تفسیرهای ژئوتکتونیکی Brander (1991) گفته شده که در زمان پرمین ورق ایران باید در موقعیت نزدیکی نسبت به هرسنین ورق توران بوده باشد باین معنی که اقیانوس تتیس شمالی پالئوزوئیک در زمان پرمو- اسکیتین به طور کامل فرورانش نموده است.

در این عقیده آمده است که حوزه تریاس آق‌دربند باقی‌مانده‌ای از اقیانوس پالئوزوئیک نمی‌باشد، بلکه آن را یک حوزه بین قاره‌ای فرض نموده که به احتمال بسیار زیاد در اثر عمل‌کرد یک رژیم تکتونیکی راستالغز به‌وجود آمده که به طور کامل با آنچه که در این نوشتار آمده هم‌خوانی دارد.

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obtained by Davoudzadeh et al. (1981) with respect to the time span of the Permian- Triassic: 'Between the Permian and the Triassic the microplate carried out a clockwise rotation ... of 40 and moved northward into a Latitude of 27 N. This was also the latitude of the southern rim of Eurasia in the Triassic, thus giving indication of a collision of Central Iran and Eurasia in Lower Triassic time. Between the Triassic and Jurassic Central Iran changed the direction of its rotational movement ... .

This was the start of an anticlockwise rotation, which ended in Early to Middle Tertiary times (Fig. 5).

A collision of the Central East Iran microplate with Eurasia in Early Triassic times and a clockwise rotation of this microplate 'between the Permian and the Triassic' were both inferred in 1981 from palaeomagnetic data alone. Geological indications were not known at that time.

Now, 10 years later, geological evidence in the Aghdarband-Fariman area supports this view. An oceanic trough, which separated Laurasia from Central Iran in Permian times, no longer existed in the Triassic, a clockwise rotation of the Central East Iran microplate could have been the cause of the Eo-Cimmerian deformations at the southern edge of Laurasia, i.e. the lateral sinistral strike- slip faulting, the oblique compression causing intense folding and thrusting, and the creation of a pullapart basin filled with Triassic sediments.

This view requires the assumption that the Central East Iran microplate was in direct contact with Eurasia during Triassic times. It also assumes that the Triassic of Nakhlak (and its metamorphosed basement) were incorporated into the Central East Iran microplate as the result of this contact. The metamorphic rocks exposed to the south of Nakhlak in the Anarak area are compared with those of 'metamorphic Hercynian units of NW-Afghanistan' (Davoudzadeh et al.,1981). Fragments of metamorphic rocks, found among the components of the thick conglomerates which compose the Baqoroq Formation at Nakhlak, as well as in the sandstone member of the Sina Formation at Aghdarband- especially in an interlayer of conglomerate (Anabeh Conglomerate, see Fig. 2)- suggest the existence of emerged land in the (? southern) neighbourhood of what was at that time the Aghdarband Sea.

The Triassic sea of Aghdarband and that of Central Iran were epicontinental seas. Between them we must assume the presence of a zone of intense strike- slip faulting, caused by clockwise Triassic rotation of the Central East Iran microplate. This horizontal displacement may have triggered the volcanic activity close to the Aghdarband Sea during Anisian- Ladinian times. It should not be surprising that the development of the Triassic north

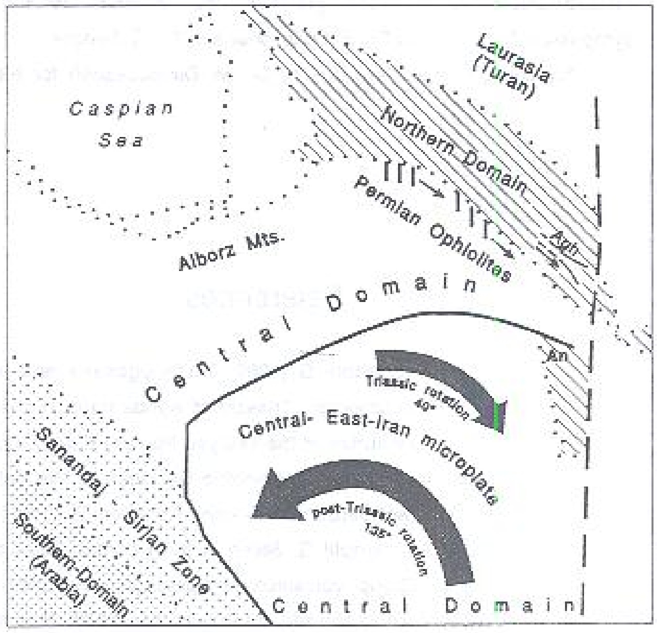

Fig. 5. Rotation of the central east Iran microplate. Section of Fig.3 in Davoudzade et al. (1981), simplified and modified by the author. Agh = Aghdarband; An = Anarak, including Nakhlak

of this zone differs from that south of this zone.

Palaeomagnetic data suggest a spreading zone between Central Iran and Eurasia in Jurassic times (Davoudzadeh et al., 1981). This may provide an explanation for the fact that in recent times the Central East Iran microplate is not in direct contact with Laurasia.

As a result of geotectonic considerations, Brandner (in Baud et al. 1991 a) states that: '... a ready in the Permian, the Iranian Plate must be positioned close to the Hercynian Turan Plate, i.e. that in this area the Northern Paleozoic Tethys ocean was entirely subducted in Permo-Scythian times ...' '...In this view, the Triassic basin of Aghdarband is not a remainder of the northern Paleozoic Tethys but a new intracontinental basin, most probably developed in an strike- slip regime ...'

This agrees exactly with the arguments presented in this paper.

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the Nazarkardeh Formation is restricted to a narrow strip along the southern margin of Triassic Laurasia over a length of 5000 km, characterizing a 'North Tethyan biogeographical subprovince' in Early Anisian times (Krystyn in Krystyn and Tatzreiter, 1991, see also Tozer, 1972).

Another characteristic of the Aghdarband Sea is the neigh-bouring intermediate to acidic volcanism, which made its first appearance during the Early Scythian and again in the Early Anisian, but had its culmination during the Late Ladinian accompanied by a subsidence of the seafloor. A back-arc basin setting of the Sea of Aghdarband is inferred by Baud and Stampfli (1989) and Baud et al., 1991 b) from these Anisian- Ladinian volcaniclastics, which are thought to be part of an 'arcuate volcanosedimentary belt (that) is traceable from the S Caucasus through Kopet Dagh to the Pamir' (Baud et al., 1991 b). However, the Permian Mashhad-Fariman oceanic trough probably no longer existed in the Triassic. Therefore, in my opinion, the existence of a Triassic subduction zone to the south of the Window of Aghdarband is most unlikely.

The Triassic sequence of Aghdarband (Fig.3) is the result of intermittent sedimentation. Two breaks in sedimentation are seen. After the first break (Late Ladinian), an interlayer of conglomerate in the lower part of the Sina Formation (Anabeh Conglomerate) contains fragments of metamorphic rocks as well as those of Carboniferous and Permian limestone, indicating dry land in the vicinity (Baud et al., 1991 b). Later, the land receded and the sea became deeper. However, during the Early Carnian a sudden shallowing of the sea, combined with the termination of volcanic activity, took place, allowing the growth of an exuberant vegetation on this seafloor in Norian times. Baud discriminates eight 'events' during the Triassic. Additionally, the Triassic sequence of Aghdarband shows considerable lateral variation of the facies. This indicates a certain unrest during the deposition of these beds. After or during deposition, or both, the beds underwent a strong deformation caused by compression and strike- slip faulting. The intensity and type of deformation suggests that the Triassic beds were deformed soon after deposition and before their final lithification had taken place.

On the whole, both the style of sedimentation and deformation of the Triassic beds supports the impression that all this occurred in a pull- apart basin along strike- slip faults during Triassic times. This ended during the Rhaetian, as black shales with another coal bed containing a Rhaetian florule (Boersma, Van Konijnenburg- Van Citter, 1991) unconformably overlie all the Eo-Cimmerian structures.

Geodynamic implications

According to most of the current geodynamic models, a Palaeozoic ocean (Palaeo- Thethys), located between Laurasia (Turan plate) and the Central Iranian microcontinent (Cimmeria), was closed during the Triassic in the course of the collision of the two plates. This collision is assumed to be the cause of the Eo-Cimmerian deformations.

The studies carried out in the north-east corner of Iran confirm the existence of a Permian oceanic trough between the two plates; however, they suggest that this oceanic trough no longer existed in Early Triassic times. Consequently, the Eo-Cimmerian structure, as exposed in the Window of Aghdarband, was probably not the immediate cause of the collision.

The southern edge of Laurasia is controlled by Eo-Cimmerian sinistral strike-slip faulting and oblique compression (Baud et al. 1991 b, Ruttner, 1991). The Triassic Sea of Aghdarband was formed there in an intracontinental pull-apart basin. Both sedimentation and the Eo-Cimmerian deformation came to an end during the Late Norian or Early Rhaetian.

Sinistral strike-slip faulting may have also occurred between the southern edge of Laurasia and the Permian ophiolite belt. However, in post- Triassic times the Permian ophiolites and Laurasia were firmly connected with each other as indicated by their common. Only slightly disturbed, Jurassic- Cretaceous cover.

With regard to Central Iran and its Triassic relation-ship with Laurasia, we refer to Davoudzadeh, et al. (1981) who, based on palaeomagnetic and geological evidence, derived the hypothesis 'that the Central-East- Iran microplate performed a 135° anticlockwise rotation since the Triassic'. Figure 5 is a simplified and modified section of their Figure 3, completed by the Permian ophiolitic belt Mashhad-Fariman.

This hypothesis is now broadly accepted. A re-rotation of the Central East Iran microplate to its assumed Triassic position as shown in Fig.5, brings the strange Triassic of Nakhlak (and the metamorphic rocks of Anarak), now exposed as inselbergs in the area north- east of Nain (eastern Central Iran), to south of Aghdarband. The striking similarity between the two Triassic sequences was one of the main geological arguments of these workers in favour of their hypothesis (cf. also Ruttner, 1984). In particular the occurrence of the Early Anisian Nicomedites fauna of Krystyn at both sites is significant (Davoudzadeh and Seyed-Emami, 1972; Davoudzadeh and Schmidt, 1982; Krystyn and Tatzreter, 1991).

Less attention was paid to the palaeomagnetic results water limestone are not feasible, as this limestone occurs not only as blocks the size of a house, but also forms limestone ridges several kilometres long. These can only be considered to have slid into the ocean from an extensive shore. Likewise, the intercalation of a graded bed, consisting of echinodermal calcirudite to calcilutite in fine grained turbidites, also has a spacious shelf as its source rather than an isolated island.

The actual time span covered by the rocks of the Mashhad-Fariman ophiolitic belt is not yet known. The late Early Permian age, established by Kozur and Mostler (1991) with respect to the pelagic part of the ophiolitic complex, relies on the conodonts of one sample only. The age of the limestone bodies established so far is, on the whole, older than that of the pelagic sample. This also favours the suggestion that these bodies slid into the oceanic trough from a neighbouring shelf.

Within the ophiolite belt no fossil evidence of Triassic age has so far been found. Eftekharnezhad and Behroozi (1991) suspect a Late Permian to very Early Triassic (?) age to be represented by the upper unit of the ophiolites. These workers also show a large area north-east of Torbat-e-Jam to consist of rocks of the Aghdarband Group in contact with Permian limestone. These rocks are described as 'coal-bearing sediments' affected by dynamothermal metamorphism and are considered to belong to the Norian Miankuhi Formation. These beds may indicate an overlap of the Triassic Sea of Aghdarband southwards over the Permian ophiolites.

The ophiolites of Fariman are probably related to those exposed at the south-west corner of the erosional Window of Aghdarband (Darreh Anjir) below their Jurassic cover; Permian limestone cropping out of this cover halfway between the two ophiolite occurrences support this assumption (Eftekharnezhad and Behroozi, 1991; Fig.1). There, at Darreh Anjir, the ophiolitic melange contains small limestone blocks of Late Permian age and is transgressively overlain by conglomerates of the Early Scythian Qara Gheitan Formation (Eftekharnezhad and Behroozi, 1991). Hence, no Triassic rocks can be part of the ophiolites there.

This present state of knowledge offers two alternatives (see also Kozur and Mostler, 1991). (1) The Permian oceanic trough Mashhad- Fariman is the remnant of a Palaeozoic ocean (Palaeo-Tethys). The ophiolites exposed in the south-west corner of the Window of Aghdarband (Darreh Anjir) may have been obducted onto the southern margin of Laurasia; the melange- type occurrence of these ophiolites supports this view. If this is so we would expect a Permian subduction zone to exist somewhere to the south of the Aghdarband Window below the Jurassic coverbeds. This agreas with current models and matches with palaeomagnetic data. However, it requires the closing of Palaeo-Tethys during latest Permian times. (2) The Permian oceanic trough was the result of Permian rifting (e. g.' opening of the Cimmerian Tethys', Kozur 1991). In this instance the northern part of the trough was already filled with alluvial sediments of the Hercynian Molasse during earliest Triassic times.

The existence of an oceanic regime immediately to the south of Laurasia (i.e. between Laurasia and the Central Iranian microcontinent) during Triassic times is in either case most unlikely.

Triassic Sea of Aghdarband

The deposition of the Early Scythian Qara Gheitan Formation, i.e. of the upper part of the Hercynian Molasse, on both the Permian ophiolites of Darreh Anjir and the southern edge of Laurasia marks the beginning of a new phase in the geological history of this area.

The clastic deposits of the Qara Gheitan Formation may range up to more than 1000 m in thickness. The uppermost part of the formation consists of black conglomerates and a volcanic litharenite of andesidic composition, grading upwards into basal beds of the Sefid Kuh Limestone (cross-bedded calcarenites, oolitic grain-stones). This marks the marine transgression on the southern edge of Laurasia (Baud et al. 1991 a).

The southernmost signs of Laurasia are found along the Shahtutak Fault as oblong shaped tectonic klippen, consisting of Palaeozoic rocks, although the actual southern edge may be still further to the south, possibly below the ophiolites of Darreh Anjir. The existence of an older, pre- Triassic, part of the Hercynian Molasse resting on the southern edge of Laurasia is inferred from the slightly metamorphosed conglomerates, sandstones and slates composing most of the schuppen zone to the south of the Triassic of Aghdarband.

The epicontinental Sea of Aghdarband was the northern marginal part of the Triassic Tethys (Tethys in general, whether oceanic or epicontinental). It had much in common with other parts of the Tethyan reaem. The late Scythian Sefid Kuh Limestone, for example, has many similarities to the lower part of the Elikah Formation of the Alborz Mountains; Brandner traces coeval Scythian sealevel fluctuations not only in the Window of Aghdarband and in the Alborz Mountains, but also as far as the Southern Calcareous Alps (Baud et al. 1991 a). In addition, the rich fauna of the Late Ladinian Faqir Marl Bed (Sina Formation), especially the ammonites, the echinoderms and the ostracods, is pan-Tethyan in character (Krystyn and Tatzreiter, 1991; Kristan-Tollmann, 1991 a; 1991 b).

On the other hand, the Early Anisian Nicomedites fauna of

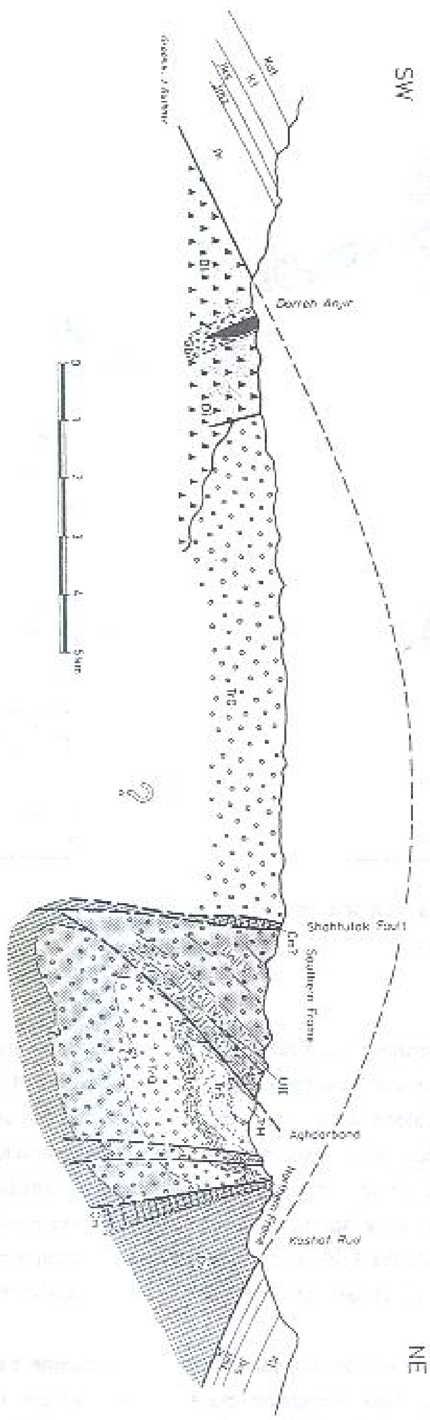


Fig. 4. General cross- section through the erosional window of Aghdarband. See Fig. 3 for legend

above- mentioned unmetamorphosed Triassic rocks. I consider this to be the overturned and thrust faulted original substratum of the Triassic.

Another major fault, the Shahtutak Fault, truncates the imbrication zone to the south-west. It is probably also a strike-slip fault. This fault also affects the Jurassic coverbeds; the geological picture on the map also suggests a sinistral lateral displacement along this fault.

Eftekharnezhad and Behroozi (1991) also report intense Eo-Cimmerian deformations in the Mashhad- Fariman ophiolitic belt. They consider the Jurassic granite intrusions of this region and the associated 'dynamothermal'metamorphism to be an after-effect of the Eo-Cimmerian orogeny.

Rocks of the Central Iranian microcontinent have been found over a distance of 20-30 Km to the south-west of the Permian ophiolitic belt. Equivalents of the Devonian Padeha, Sibzar and Bahram Formations, known from the Shirgesht-Ozbak-Kuh area (north of Tabas), are exposed along the southern slopes of the Binalud Mountains (south-east of Mashhad) as tectonic slices between the Binalud phyllites (see Lammerer et at., 1983); the same formations plus the Permian Jamal Formation and the Triassic Shotori dolomite Formation are shown to the south-west of the Fariman- Torbat-e-Jam depression (to the west of Torbat-e-Jam) on the Kariz-Now sheet of the 1984 Geological Map of Iran (1:100 000) (cf. Fig 1).

Discussion

The following features outcrop below their Jurassic-Cretaceous cover: (1) the remnants of a Permian ocean floor over a longitudinal extent of 150 Km; and, 40 Km to the north-east, (2) the southern edge of Laurasia, covered by remnants of a Triassic sea, the 'Sea of Aghdarband showing an Eo-Cimmerian structure controlled by (sinistral) strike-slip faulting and by compression from the south-west.

Permian ocean floor

In my opinion this ocean floor belonged not to a wide ocean, but more likely to a narrow oceanic trough. The shallow water limestones, which are embedded in the pelagic sedimentary rocks, obviously originated from a nearby shelf region, which must be assumed to have been to the south of the oceanic trough as carbonate rocks of Permian age are not known in the adjoining northern regions. The (partly sparry) limestone has yet to be compared in detail with Permian limestones of the Alborz Mountains (e.g. the Ruteh Limestone) or with those of Central Iran (e. g. the Jamal Limestone). Seamounts as a source of the shallow

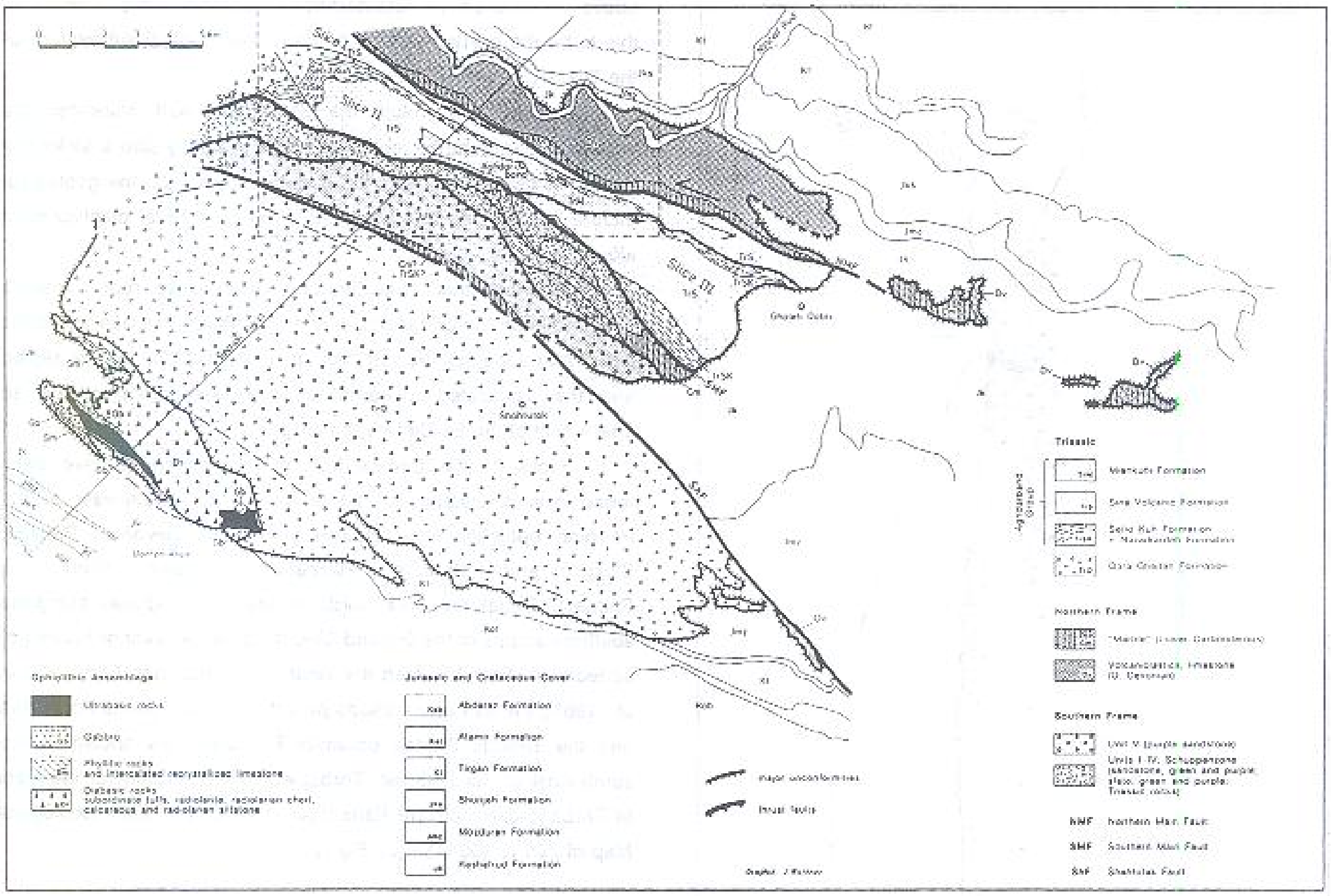


Fig. 3. Erosional window of Aghdarband. Tectonic sketch map based on the geological evidence obtained by Eftekharnezhad and Behroozi and by the author's fieldwork

(5) The ophiolites of Darreh Anjir, exposed in the south-west corner of the window (Eftekharnezhad and Behroozi, 1991) are mainly of melange-type (diabasic rocks mixed with tuff, radiolarite, radiolarian chert and siltstone), associated with ultrabasic rocks, gabbro and phyllitic shale. Small limestone blocks contain a Late Permian microfauna (Kashani and Bozorgnia in Eftekharnezhad and Behroozi, 1991).

Structure

The Eo-Cimmerian structure is well exposed within the erosional Window of Aghdarband (Fig.4); it is characterized by an oblique compression from the south-west and by (sinistral) lateral strike-slip faulting.

The Triassic beds are squeezed between a sinistral strike-slip fault ('northern main fault'), which borders these beds to the NNW against the Palaeozoic rocks, and a thrust fault ('southern main fault') along which the imbrication zone is thrust over the Triassic beds from the south- west. The internal structure of the Triassic is a broad syncline accompanied by an anticline in the western part of the Aghdarband area, the fold axes being inclined 20-30 towards the ESE, and a synclinorium consisting of three to four narrow synclines combined with a thrust fault in the eastern part.

An intensive small scale folding of sandstone beds of the volcanogenic Sina Formation close to the northern main fault shows a colckwise rotation coinciding with a steepening of the fold axes, thus indicating a sinistrallateral movement along this fault (Ruttner, 1991).

The imbrication (schuppen) zone (southern frame of the Triassic) consists of several thrust slices, the lowest containing the

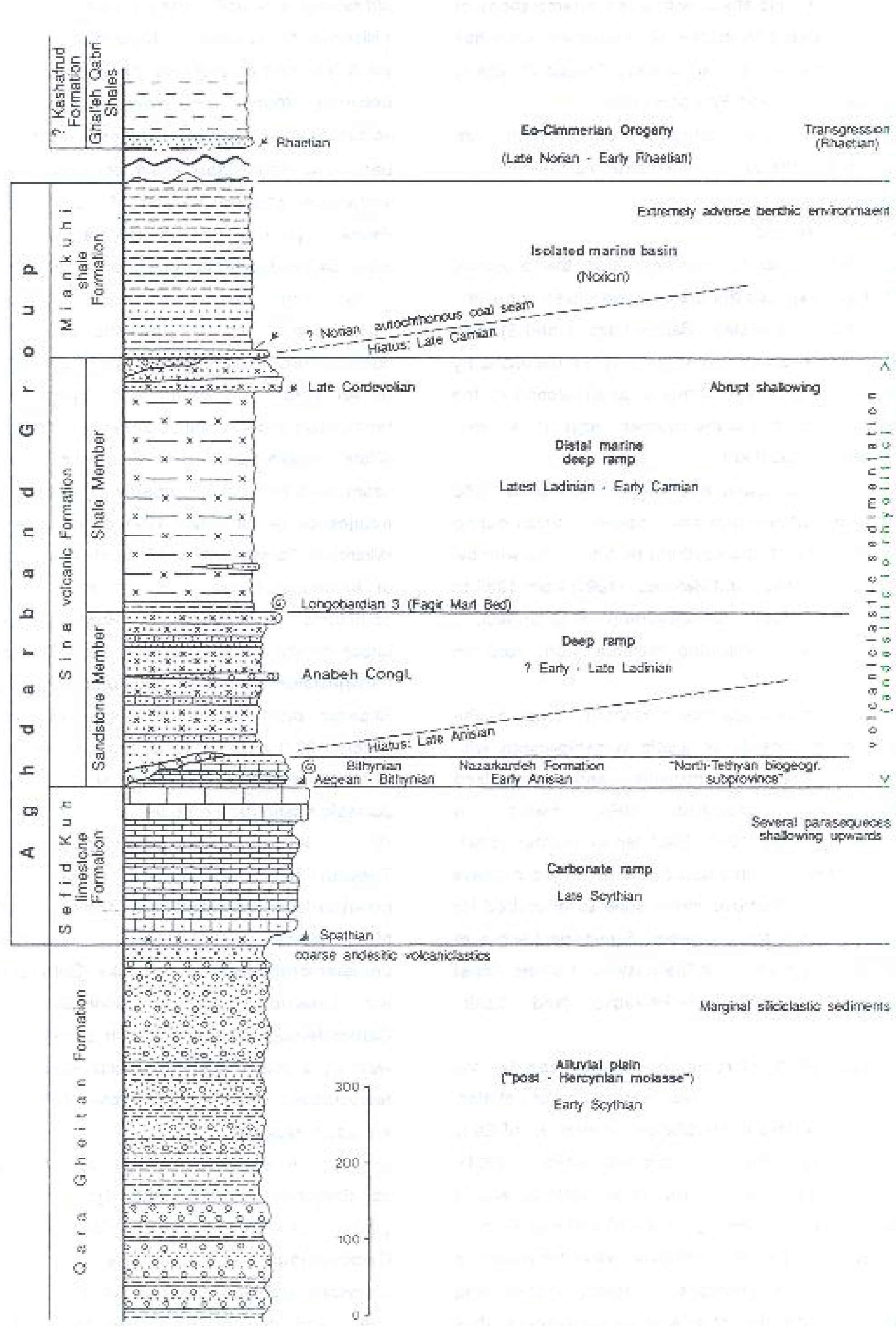


Fig.2. Triassic of Aghdarband: General columnar section

The upper unit is composed mostly of fine clastic sedimentary rocks and phyllitic shale, with a few intercalations of basic spilite and recrystallized limestone. No faunal evidence has been found in this unit; a Late Permian to Early Triassic (?) age is suggested by Eftekharnezhad and Behroozi (1991).

To the north-east, the ophiolites of Fariman are unconformably overlain by the Jurassic Kashafrud Formation.

Erosinal Window of Aghdarband

Forty kilometres further to the north-east the erosional Window of Aghdarband exposes the pre-Jurassic basement of the south-eastern part of the Kopet Dagh Range (Figs. 1 and 3). This window shows Eo- Cimmerian structural features not disturbed by subsequent deformation, that is, it shows a small section of the Eo-Cimmerian structural pattern at the southern edge of Laurasia. The window has a size of 15x20 Km.

The Window of Aghdarband has been known since 1956 (Goldschmid, 1956). Its northern part was mapped in detail during 1975 and 1976 (Ruttner, 1991); the southern portion of the window was mapped by Eftekharnezhad and Behroozi (1991) from 1985 to 1988 in the course of the Torbat-e-Jam quadrangle map project.

The window shows the following features (from north to south, Fig.3).

(1) A Palaeozoic rock sequence ('northern frame' of the Triassic). This sequence consists of acidic volcanic-lastics with limestone intercalations (Frasnian- Fammenian) and recrystallized limestone (Tournaisian; Schonlaub, 1991; Hamdi in Eftekharnezhad and Behroozi, 1991; Kirchner in Ruttner, 1991; Ruttner, 1991). The Upper Devonian part of the sequence displays a striking similarity with the Kartdzhurskaya suite as described for the parautochthonous part of the Caucasian Forerange (Belove et al., 1978). This supports the view that the basement of the Kopet Dagh Range was part of laurasia in Late Palaeozoic (and Triassic) times.

(2) The Triassic of Aghdarband is characterized by the following features (Fig.2). (a) A red sequence of shales, sandstones and conglomerates (Qara Gheitan Formation) of Early Scythian age (Ruttner, 1991; Eftekharnezhad and Behroozi, 1991); it is deposited on an alluvial plain (Baud et al., 1991 b) and is equivalent to the upper part of the Hercynian Molasse of Russian geologists (Belov et al., 1978). (b) A shallow water limestone of Late Scythian age (Sefid Kuh Limestone Formation), representing a carbonate ramp and consisting of several parasequences, thus being 'the product of a transgression- regression cycle' (Baud et al., 1991 a); there are striking similarities with the Elikah Formation of the Alborz Mountains. (c) Alternating beds of nodular limestone and tuffaceous shale/sandstone (Nazarkardeh Formation) containing a specific Early Anisian (Bithynian) ammonite fauna ('Nicomedites association',Krystyn in Krystyn and Tatzreiter, 1991). (d) A late Anisian erosional phase (hiatus), indicated by a locally occurring monomictic limestone conglomerate. (e) A thick volcaniclastic- turbiditic sequence (Sina volcanic Formation), becoming increasingly shaly upwards and containing a second ammonite- bearing horizon of Late Ladinian age (Romanites Fauna, Krystyn in Krystyn and Tatzreiter, 1991); an increase in water depth upwards is indicated by finegrained (distal) turbidites in the upper shaly part of the volcanogenic sequence; the volcaniclastics are of andesitic to trachytic (even rhyolitic) composition, becoming more acidic upwards (Baud et al. 1991 b). (f) An abrupt shallowing and drying up combined with the termination of the volcanic activity during Early Carnian times. (g) A late Carnian hiatus in secimentation. (h) An autochthonous coal seam (with root clay). probably of Norian age (Boersma and Van Konijnenburg- VanCittert, 1991) at the base of monotonous shales (Miankuhi Formation), which contain a poor species assemblage of benthonic foraminifers, indicating extremely adverse living conditions (Oberhauser in Ruttner, 1991). (i) An angular unconformity, indicating the Eo- Cimmerian orogeny. (j) A transgression- a white sandstone containing coal streaks and Rhaetian plant remains (Boersma and Van Konijnenburg- Van Cittert. 1991) at the base of black shales (Ghal'eh Qabri Shales). possibly representing lowermost basal parts of the otherwise Jurassic Kashafrud Formation.

(3) An imbrication (schuppen) zone ('Southern frame'of the Triassic). This is composed of slightly metamorphosed red and green sericitic slates and hard sandstones (probably lower parts of the Hercynian Molasse), tectonically mixed with unmetamorphosed Triassic rocks (Qara Gheitan Formation, Sefid Kuh Limestone) and of recrystallized limestone (probably Carboniferous). This imbrication zone is truncated to the south-west by a major fault (Shahtutak Fault), along which bodies of recrystallized limestone and those of (?) Devonian volcaniclastics are again exposed.

(4) A wide area formed by red shales, sandstones and conglomerates of the Early Sythian Qara Gheitan Formation (upper part of the Hercynian Molasse). Microfossils of Carboniferous and, in one case, Late Permian age are found in limestone pebbles (Kashani in Eftekharnezhad and Behroozi, 1991) and its position below the Late Scythian Sefid Kuh Limestone fix the age of the Qara Gheitan Formation as Early Scythian. A conglomerate bed containing pebbles of radiolarite and ultrabasics rests transgressively on ophiolites.

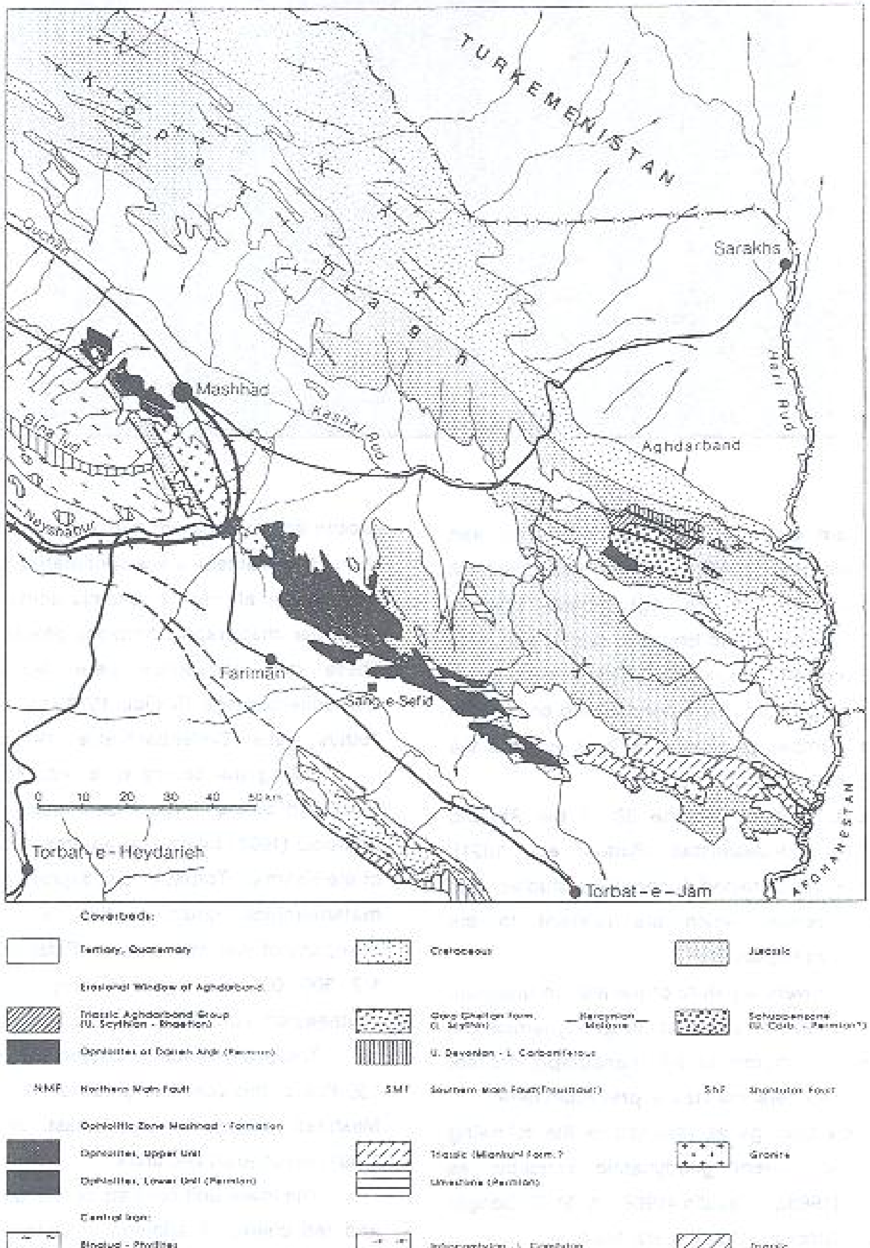
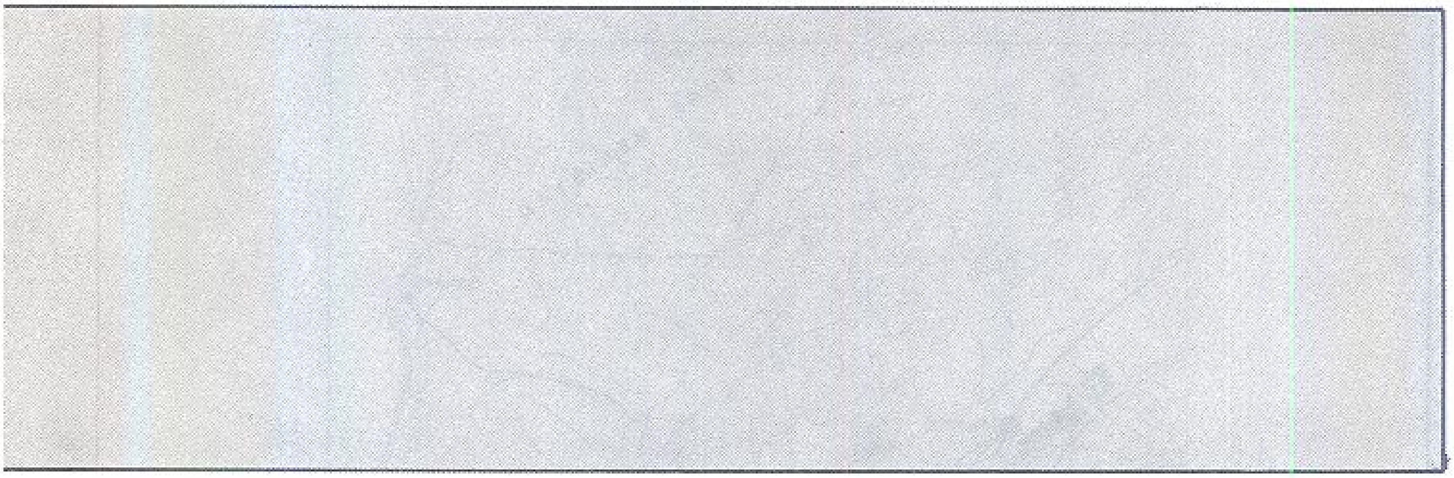


Fig.1. Erosional Window of Aghdarband and the Permian Mashhad- Fariman ophiolitic belt. A geotectonic sketch map based on the 'Preliminary Geological Map of KE- Khorasan' (Fig. 1 in Eftekharnezhad and Behroozi. 1991), with additions from the 1:1000000 (sheet No. 3) Geological Map of Iran (NIOC 1977), the 1:250 000 Geological Quadrangle Map of Iran (sheet No. K-4, Mashhad; GSI, 1986), the 1:100 000 Geological Map of Iran (sheet No. 8060; GSI, 1984), the Geological sketch map of the Binalud Mountains west of Mashhad (Fig. 1 in Lammerer et al., 1983) and the tectonical sketch map of the erosional window of Aghdarband (Fig. 1 in Ruttner, 1991)



map sheet Torbat-e- Jam by the Geological Survey of Iran (Eftekharnezhad and Behroozi, 1991), and by stratigraphical studies in the northern part of the Aghdarband Window accomplished by Baud (Lausanne) and Brandner (Innsbruck), who visited the area in 1972 and 1977, respectively, The present author prepared a detailed geological map of the Aghdarband coalfield in 1975 and 1976, and a number of specialists have studied the fossils and rock samples collected in this area.

A monograph, published as volume 38 of the Abhand lungen der Geologischen Bundesanstalt (Ruttner ed., 1991), contains in detail all the results obtained during these studies. This paper summarises the results which are relevant to the geodynamic problems of this region.

Considering the controversial nature of the area in question, it is easy to understand that the views of its geodynamics, as expressed by individual contributors to the monograph, are not wholly in agreement. My own personal view is presented here.

Alltogether, the new findings as reported in the following lead to modifications to current geodynamic concepts as presented by A. A. Belov (1986), J. Boulin (1988), A. M. C. Sengor (1985, 1986, 1990) and J. Stocklin (1977), 1980, 1984).

Geological Record

Permian ophiolites of Mashhad- Fariman

Ophiolitic rocks have been known to outcrop in the area to the east and north east of the town of Mashhad since 1971 (Majidi and Alavi- Tehrani, 1971; Majidi, 1978; 1981); Geological Survey of Iran, 1986). They are exposed as basic and ultrabasic rocks (dunite, wehrlite, antigorite- rich serpentinite, pyroxene bearing gabbro and metabasalt),metamorphosed pelitic rocks, banded red cherts (radiolarites)- a few centimetres to a few metres in thickness immediately above the volcanic units- , and a band of marble in the lower stratigraphic horizons (Weber- Diefenbach et al., 1986). These rock sequences were thought to be of Devonian-Carboniferous age (Majidi, 1978) and to be remnants of Palaeo-Tethys (Weber- Diefenbach et al., 1986).

During the course of a mapping project in the northern-most part of the Torbat-e-Jam quadrangle, Eftekharnezhad and Behroozi (1991) found that an area immediately to the north- east of the Fariman- Torbat-e-Jam depression (shown as'slates, schists, metamorphics, undiff.'on the 1977 1:1 000000 National Oil Company of Iran map and as 'Palaeozoic- Mesozoic' on the 1985 1:2 500 000 Geological Survey of Iran map) represent the southeastern continuation of the Mashhad ophiolites (Fig.1).

These new findings extend the ophiolitic zone to a total of 150 Km. In this zone the grade of metamorphism decreases from Mashhad towards the south- east. Eftekharnezhad and Behroozi (1991) distinguish two units.

The lower unit consists of fine grained turbidites, radiolarites and red cherts, in addition to slates, pillowlavas and ultramafic rocks. A sample of red chert, collected east of the village Sang-e-Sefid, yielded pelagic conodonts of late Early Permian (Late Kungurian) age (Kozur and Mostler, 1991). Embedded in the pelagic sedimentary rocks are huge bodies of shallow water limestone; these contain a microfauna of Early (to Middle) Permian age (Asselian- Sakmarian, and Sakmarian- Murghabian, respectively; Bozorgnia in Eftekharnezhad and Behroozi, 1991). The present author also saw a bed, 2m thick, of an echinodermal calcarenite intercalated between turbiditic siltstone and diabase and showing graded bedding.

Southern borderland of Triassic Laurasia in north-east Iran

By: Dr. A. W. Ruttner *

Abstract

Results obtained by Iranian and European geoscientists in the critical area to the north-east of the North Iran Suture east of Mashhad are desribed and discussed. A slightly metamorphosed ophiolite belt, outcropping as the south easterly continuation of the previously known ophiolites of Mashhad along the north eastern perimeter of the Fariman- Torbat-e-Jam depression, proved to be either the remnant of a Permian ocean floor or more likely the remnant of a narrow ocean trough. There is as yet no proof of a Triassic age for this ophiolitic belt. To the north of this ophiolitic belt an epicontinental Triassic sequence is exposed at the southern edge of Laurasia in the erosional Window of Aghdarband. This is the result of intermittent sedimentation in a pull- apart basin along sinistral strike- slip faults. The Triassic of Aghdarband has much in common with other deposits of the Triassic Tethys; however, it shows a few unique features, e.g. the Early Anisian Nicomedites fauna of a palaeobiogeographic North Tethyan Subprovince, or volcanogenic sedimentation during the late Anisian and the entire Ladinian.

Permian ophiolites outcropping at the south- west corner of the Aghdarband erosional Window are transgressively overlain by basal conglomerats of this Triassic sequence. Hence the existence of a Triassic ocean south of Laurasia is very unlikely. This is an agreement with paleomagnetic data which suggest that the Central Iranian microcontinent was in direct contact with Laurasia during Triassic times. These palaeomagnetic data also suggest a clockwise rotation of the Central East Iran microplate during Triassic times (contrary to the anticlockwise rotation of this microplate in post- Triassic times). The sinistral strike- slip faulting and compression from the south- west which controls the structure of the Triassic may be derivative sequels to this clockwise rotation. All Eo- Cimmerian deformations of the Triassic rocks (e. g. folding, thrust faulting, strike- slip faulting) had stopped by Rhaetian times.

Introduction

The area to the east and south- east of the town of Mashhad forms part of the much disputed borderland between the Central Iranian microcontinent and Laurasia (Turan), i. e. between the 'Central Domain' and the 'Northern Domain' (Stocklin, 1977), or between the 'Cimmerian Continent' and Laurasia (Sengor, 1990). Unfortunately, the pre-Jurassic basement is only exposed in two regions: (1) to the north and along the Fariman- Torbat- e- Jam depression and (2) within the erosional Window of Aghdarband, the latter being situated in the eastern part of the Kopet Dagh Range (Fig.1).

These two regions have been studied in detail over the past 15 years in the course of preparing the geological quadrangle