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POVIJEST ISTRAŽIVANJA I EKSPLOATACIJE BITUMINOZNIH I KEROGENIH NALAZIŠTA HRVATSKE

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Ključne riječi: Nalazišta, Bitumen, Kerogen, Povijest Geologija, Rudarstvo

Najstarija ležišta prirodnog bitumena, odnosno asfalta, u primorskoj Hrvatskoj, pretpostavlja se da su bila eksploatirana već u srednjem vijeku. Sigurni pisani dokumenti o Vinišču kod Trogira potječu iz 1628., a o vrgoračkoj Paklini iz 1753. Do kraja XVIII. stoljeća otkriveno je u Dalmaciji više nalazišta,no značajni su bili Škrip na otoku Braču i Suhi Dolac.

Najstarija nalazišta i ležišta kerogenih stijena, odnosno "bituminoznih" ili "uljnih škriljavaca" spominju se kao kameni ili fosilni ugljeni u Sovinjaku u gornjem toku rijeke Mirne i u Rebićima u Istri, zatim kod Sinja, Slivna nedaleko Neretve, Mirce ("Smirče") i kod Nerežišća na Braču. Sva su ona opisana 1804., a Sovinjak se spominje već u XVI. stoljeću.

Naše najstarije nalazište oksidiranog zemnog ulja je Peklenica u Međimurju, a pretpostavlja se da je bila poznata već u XVI. stoljeću.

Izložene su i nove spoznaje o rudarsko-geološkim istraživanjima bituminoznih i kerogenih stijena i ležišta.

Key-words: Deposits, Bitumen, Kerogen, History, Geology, Mining

It is assumed that the first known sediments of natural bitumen or asphalt in coastal Croatia were exploited as the early moddle ages. Yet authenticated written documents about Viniśće near Trogir derive from no earlier than 1628, about Vrgorac/Paklina from only 1753. By the end of the 18th century, many deposits were discovered in Dalmatia, but it was Škrip on the Island of Brač and Suhi Dolac that were important.

The earliest known deposits and occurrences of kerogenous rocks, or bituminous or oil shales, are mentioned as stone or fossil coal in Sovinjak, in the upper course of the River Mirna, and in Rebići in Istria; near Sinj, Slivno not far from the River Neretva, Mirca and near Nerežišće on the Island of Brač. All if these were well known and described in 1804, while Sovinjak was mentioned in the 16th century.

In the article, some of new information derived from mining and geological research into bituminous and kerogenous sediments and deposits are provided.

Uvod

Povijest istraživanja i eksploatacije bituminoznih nalazišta, odnosno prirodnih asfalta te kerogenih nalazišta, odnosno "bituminoznih" ili "uljnih škriljavaca" nekada zamjenjivanim s "kamenim" ili "fosilnim ugljenom", povezuje se u nas, po starim dokumentima za rani novi vijek. Tada su zabilježeni prvi podaci o kopanju "pisasfalta" (piss asphaltus) "blizu Hvara nedaleko od Neretve" u Dalmaciji (M at t h i o l i, 1565), "zemnog voska" u Panoniji i "pegole" (pakline) u Viniśću 1628. i 1668. (P r i u l i, 1668, B a r b a r o, 1670).

U Hrvatskoj pronalaze se u XVIII. i XIX. stoljeću nova nalazišta pakline i otvaraju rudnici (Paklina, Škrip i dr.). Sredinom XIX. stoljeća započinje kod nas i prerada pakline (Viniśće, Škrip i dr.). Pored toga, dio asfalta se izvozi i prerađuje u Veneciji. Vrhunac proizvodnje asfalta dostignut je u drugoj polovini XIX. i početkom XX. stoljeća.

Jeli asfalt kopan u nas i u srednjem vijeku može se nagađati , no s asfaltom (pegolom) se svakako trgovalo. O tome postoje dokumenti iz XV. stoljeća, poput zapisa u oporuci zadarskog svećenika *Zubine* iz 1437. (Š u r m i n, 1898). Na poleđini oporuke zapisano je da mu je *Š. Račić* dužan za "pakal" (bitumen) 39 bolanč. U spisu iz 1381. zadarskog bilježnika Petrusa de *Sercane,* koji je saslušao kapetana talijanske barke *Simon* pok. *Baghinija* de *Bertanora*, piše da je isti pokušao prikriti u barci 12 bačvi bitumena ("pegola").

Istraživanja i eksploatacija kerogenih stijena (uljnih škriljavaca") vezana su sa sigurnošću za novi vijek i to za konac XVIII. stoljeća kad je 1782. spomenuto bračko nalazište Smriče kod Mirce i neka manja nalazišta na kopnu, te za konac XIX. stoljeća, kada su otkrivena naša najveća nalazišta Ruda kod Sinja kao i plješivički uljni škriljavci: Vrelo Koreničko, Baljevac, Zavalje i dr.

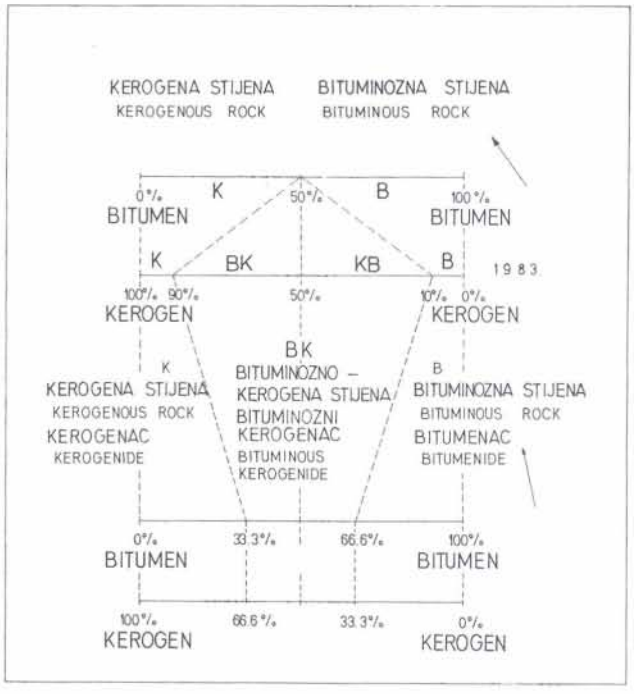
U prošlosti je primjena prirodnih bitumena i umjetnog katrana imala veliko značenje za hidroizolaciju drvenih brodova i u ratnim potrebama, a "uljnih škriljavaca" ponajprije u zdravstvu, veterini i dr. Svoju najznačajniju primjenu dosegnula je u XIX. i XX. stoljeću kao alternativni izvor energije. Cilj je ovih istraživanja upoznati povijest jedne grane rudarstva koja je u prošlosti bila dosta značajna u gospodarstvu Hrvatske, a posebice Dalmacije i Like. Željelo se dobiti više uvida u našu ranu rudarsku poduzetničku djelatnost, a i prikazati iskustva iz obnovljenog rudarsko-geološkog istraživanja bituminoznih i kerogenih nalazišta Hrvatske.

Prirodni bitumen i kerogen u stijenama

Prema preporuci studijske grupe World Petroleum Congress (M a r t i n e z et al. 1987) "prirodni bitumen je dio nafte koji se nalazi u polukrutom stanju u prirodnim nalazištima. To je smeđa do crna

ljepljiva i rastezljiva tvar, a sastoji se pretežno od ugljikovodika (66%-89%), te od vodika (7%-12%), sumpora (1%-10%), dušika (<1%) i kisika (1%-2%). Heteroelemenata ima najčešće <10%. Često je onečišćena mineralnom tvari, a ako infiltrira i/ili impregnira stijenu tada je to bituminozna stijena.

Poznati sinonim za bitumen (lat.) je asfalt (grč.). Taj je izraz kasnijom uporabom u Europi poprimio homonimsko značenje, jer se upotrebljava za stijenu infiltriranu i/ili impregniranu prirodnim bitumenom. Stariji hrvatski izrazi za bitumen su *pakal* (V r a n č i ć, 1595) ili *pek(e)l,* koji S k o k (1972) povezuje s paklom. Paklina ili Paklenica su u nas ponegdje geografski nazivi nalazišta prirodnog bitumena, odnosno asfalta.



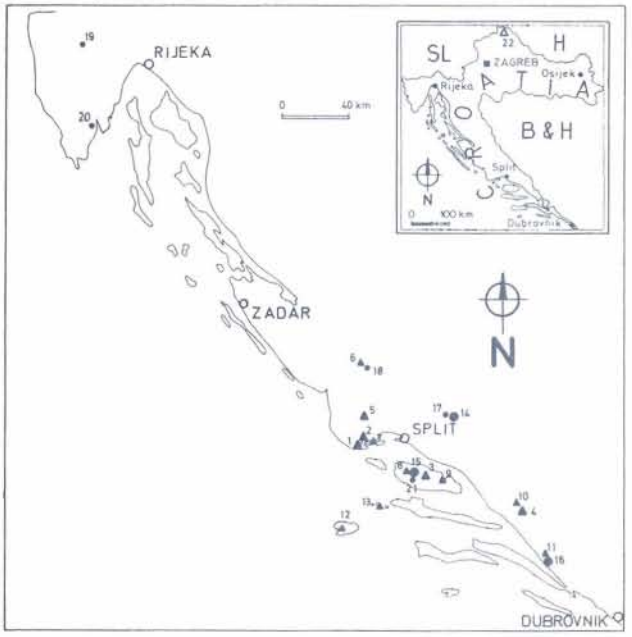
Sl. 1. Podjela stijena prema odnosu bitumena i kerogena u ukupnoj organskoj tvari. Nazivi u gornjem dijelu slike:
K - kerogene stijene (u užem smislu riječi),
BK - bituminozno-kerogene stijene,
KB - kerogeno-bituminozne stijene,
B - bituminozne stijene (u užem smislu riječi)
(prema Š e b e č i ć u, 1983)
Strelica (desno) predstavlja niz:
bitumen - bitumenac - bituminozna stijena
Sličan je niz:
kerogen - kerogenac - kerogena stijena

Fig. 1. The division of rocks according to the proportion of bitumen and kerogen in the total organic matter. The terme in the upper part of Figure:
K - kerogenous rocks (in a narrower sense),
BK - bituminous-kerogenous rocks,
KB - kerogenous-bituminous rocks,
B - bituminous rocks (in a narrower sence)
(after Š e b e č i ć, 1983)
Arrow (on the right) represents a sequence:
Bitumen - bitumenide - bituminous rocks
A similar sequence is:
kerogen - kerogenide - kerogenous rocks

Izraz bitumen prevodio se i sa smolom (B e l l o s z t e n e c z, 1760).

"Bituminozni škriljavci" su smjese organske i anorganske tvari iz kojih se dobiva ulje, pa odatle naziv i "uljni škriljavci". Uljne škriljavce karakterizira vrlo tanki stratiformni položaj naslaga. Više ili manje su obogaćeni s organskom tvari, kasnije nazvanom kerogen, pa odatle i nazivi kerogene stijene (S c h l a t t e r 1968, Y e n et al., 1976). Naziv ukazuje da se njegovim zagrijavanjem dobiva (parafinski) vosak ili ulje. Kerogen je fosilizirana organska tvar netopiva u uobičajenim organskim otapalima, dok je bitumen topiv (D u r a n d, 1980). Kerogene stijene mogu biti zanimljive za naftno-geološka istraživanja, ako su zrele, jer su matične stijene za ugljikovodike.

Ima li u stijeni u organskoj tvari kerogena i bitumena (sl. 1) tada su to bituminozni kerogenci ili kerogeni bitumenci, ovisno čega ima više (Š e b e č i ć, 1983).



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Sl. 2. Karta bituminoznih i kerogenih ležišta i nalazišta prije XVIII. stoljeća

Fig. 2. Map of bituminous and kerogenous deposits and occurrences before 18th century
(1) bituminozna ležišta *(bituminous deposits)*:
1-Vinišće-"Opatija" (?B), 2-Vinišće-"Biskupija" (B),
3- Brač "Škrip" (B), 4-Vrgorac-"Paklina" (BK-B),
5-Suhi Dolac (Primorski Dolac-Balovi)
(2) bituminozna nalazišta *(bituminous occurrences)*:
6-Siverić-"Badanj" (?B), 7-Čiovo-"Sv. Andrija" (B),
8-Brač-Smirča (B,K), 9-"Pučišća"- "Sv. Ivan" (?B),
10-Vrgorac-Kotezi (?B), 11-Slivno (?B),
12-Komiža (?B), 13-Pakleni otoci (sec. B)
(3) kerogena ležišta *(kerogenous deposits)*:
14-Sinj (K), 15-Brač-Smirča (K), 16-Slivno (K)
(4) kerogena nalazišta *(kerogenous occurrences)*:
17-Sinj (K)-"Đipalovo vrilo" (?K), Siverić (?K),
19-Sovinjak (?K), 20-Barban-Rebići (K),
21-Brač-Nerežišće (?K)
(5) nafta-bitumen *(crude oil)*:
22-Peklenica

Tablica 1.
Table 1.

Proizvodnja prirodnog asfalta (u tonama)
Production of Native Asphalt (in tons)
Hrvatska
Croatia

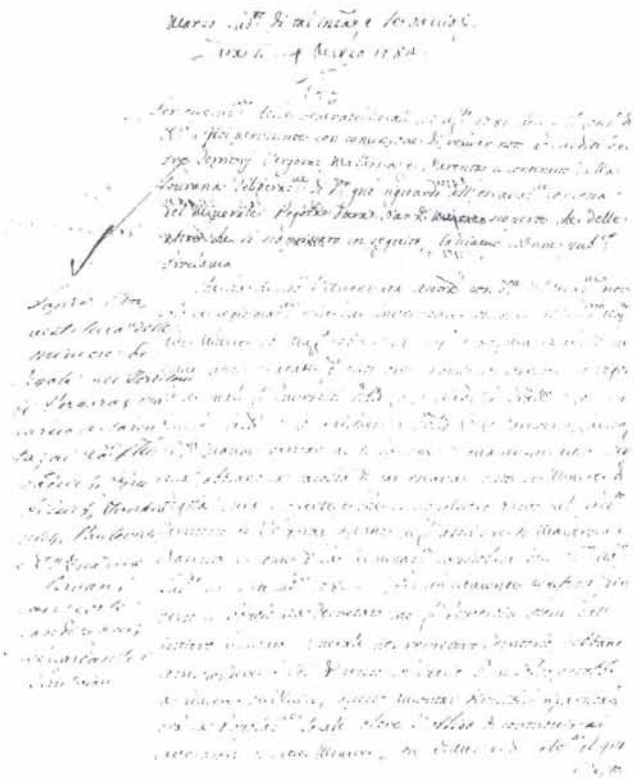
GODINA *(YEAR)*	1905	1910	1913	1921 -22	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
PROIZVODNJA *(PRODUCTION)*	3894	2200	2880	550	97	286	85	109	0	69	233	66	109	140	(32) mj. *5mon.*	116	(14) mj. *2mon.*	107	147	130	(65) mj. *5mon.*
BROJ RADNIKA *(NO. OF WORKERS)*	30-50				11	15	8	6		3-6	1-12	2	6	7	8-10	5			5		

Lokalitet Vrgorac-"Paklina" *(Locality)*

GODINA *(YEAR)*	1898	1902-1914	1921	1922	Za razdoblje *(for the period)* 1924 - 1940, vidi proizvodnju u Hrvatskoj *(see production in Croatia)*
PROIZVODNJA *(PRODUCTION)*	3000	24720	230	270	
BROJ RADNIKA *(NO. OF WORKERS)*		30-50		39-50	

GODINA *(YEAR)*	1954 1957	1958 1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
PROIZVODNJA *(PRODUCTION)*	4000	3200	632	512	7	708	(256) mj. *6mon.*	0	0	530	240	0	280	0	240	200	185	210	281	103	0	194	(160) mj. *6mon.*
BROJ RADNIKA *(NO. OF WORKERS)*							15																

Od 1961. površinska eksploatacija
Since the year 1961 surface exploitation



Sl. 3. Hrvatski poduzetnici: Kačić, Grubišić, Ivičević, Pavlović i Pervan dobili su odobrenje 27.8.1781. za iskopavanje krutog bitumena na području Vrgorca, Makarske i Neretve. Ova se dozvola povezuje za prijašnja odobrenja, pa i ono od 26.5.1753. (B o l d u, 1782)

Fig. 3. Croatian Entrepreneurs: Kačić, Grubišić, Ivičević, Pavlović and Pervan obtained the approval on August 27, 1781 for excavation of solid bitumen in the areas of Vrgorac, Makarska and Neretva. This approval is connected with the earlier ones, so far back as that of May 26, 1753 (Boldu, 1782)

Prevladava li pak u ukupnoj organskoj tvari bitumen (>90%) tada su to "čisti bitumen(c)i".

Prvu složenu podjelu bituminoznih karbonatnih stijena načinio je autor (Š e b e č i ć, 1978) prema strukturno-teksturnim svojstvima karbonatnih stijena, uključujući njihov mineralni i kemijski sastav, zatim prema podjeli bitumena i pora u stijeni u kojoj se nalazi bitumen.

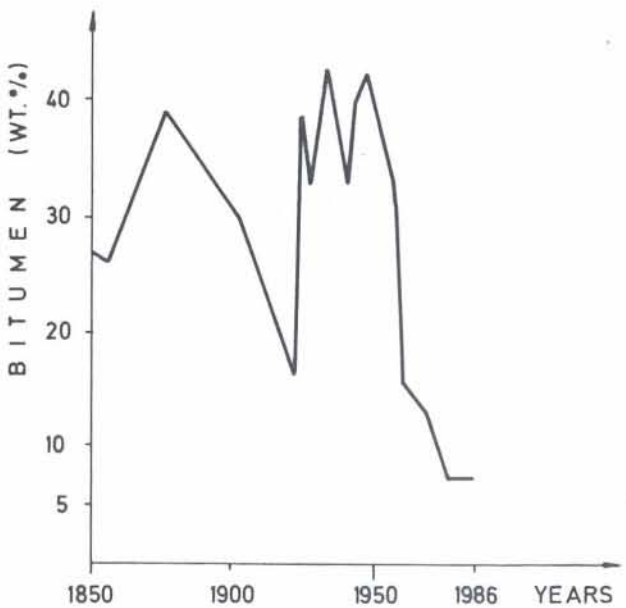
Potrebno je istaknuti da u jalovim stijenama s vrlo niskim sadržajem organske tvari mogu postojati odnosi bitumena i kerogena u ukupnoj organskoj tvari, kao i u "pravih" bituminoznih, bituminozno-kerogenih i kerogenih stijena, što nema praktično značenje u primjeni, izuzev ako se studiraju odnosi u akumulaciji i migraciji navedenih sastojaka.

Osim podjela temeljenim na odnosu sadržaja bitumena i kerogena u ukupnoj organskoj tvari (sl. 1), moguće je u skladu s podjelom S c h m i t z a (1986) jednotipne organolite s asfaltom, koje on naziva "sirovi asfalt" nazvati "a s f a l t a c". Korigirani bi niz tada glasio: čisti asfalt - asfaltac - asfaltna stijena, što bi sa sinonimom "bitumen" u našim

razmatranjima bilo: bitumen- bitumenac-bituminozna stijena, te niz: kerogen-kerogenac-kerogena stijena. Temelj ovih podjela svodi se na sadržaj mineralne tvari <10%, 10%-50% i >50%. U složenim podjelama s bitumenom i kerogenom naziv se određuje prema prevladavajućem tipu organske tvari.

Bituminozna ležišta i nalazišta

Prema poznatim objavljenim podacima jedno od najstarijih nalazišta smolastog asfalta (pissasphaltus) nalazi se "blizu Hvara nedaleko od Neretve" (M a t t h i o l i, 1565), a što se može odnositi na vrgoračku Paklinu ili neretvljansko Slivno (sl. 2). F o r t i s (1774) pretpostavlja da je vrgoračkí rudnik radio prije nego što je "mletačko oružje osvojilo ovaj kraj". To se i čini logičnim, jer samo je veliko nalazište moglo imati dugu povijest eksploatacije. O asfaltnom nalazištu **Paklina** postoje dokumenti iz arhiva (B o l d u, 1782) iz kojih je vidljivo da je hrvatsko rudarsko poduzetništvo u vrgoračkom kraju bilo dobro organizirano već 1753. (sl.3), a o tomu su pisali N o v a k (1962), S o l d o (1978), P e r i č i ć (1980) i dr. K i š p a t i ć (1901) piše, prema navodima F r i e s e a, da su "asfaltni kamen u Vrhgorcu već pred 150 god. (tj. 1708, op. *Šebečića*) vadili, pa da su se radi njega mnoge pravde vodile".



Sl. 4. Sadržaj bitumena u prirodnom asfaltu vrgoračke Pakline
Fig. 4. Contents of bitumen in the natural asphalt of Paklina-Vrgorac

Sl. 5. Cijeđenje bitumena iz kaverne na površinskom kopu Paklina- Vrgorac (foto:J. Bulić)
Fig. 5. Seepage of bitumen from a cave in an open pit Paklina-Vrgorac (Photo: J. Bulić)

U Dalmaciji je rudarska proizvodnja u 1850. iznosila približno 1000 bečkih centi (bč.c) (56 t) asfalta i preko 40 000 bč.c (2240t) asfaltnih stijena, koje su prevozili u Veneciju na pripremanje asfaltnog mastiksa (F r i e s e, 1852).

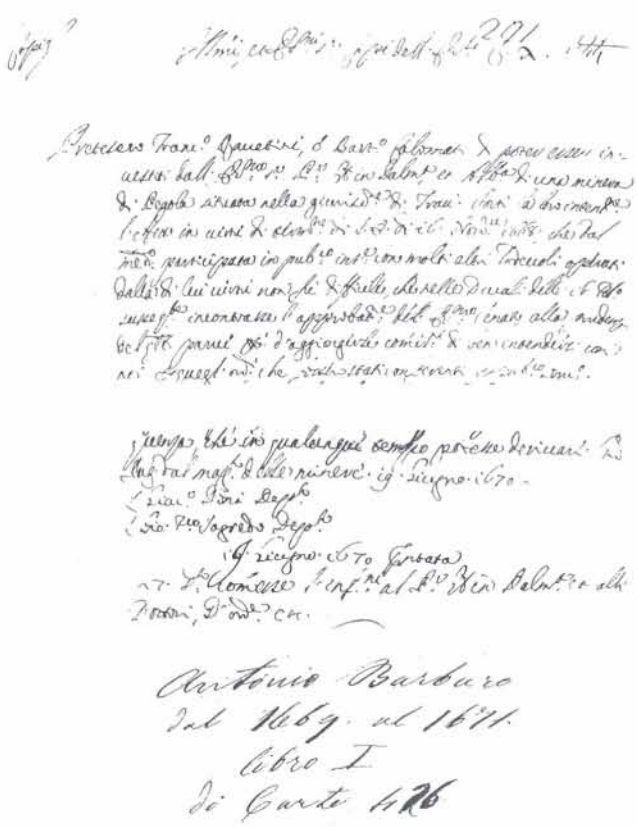
Rudarsku aktivnost u Paklini sredinom XIX. stoljeća nastavlja barun *R o t s c h i l d*, a od njega rudnik preuzima tvrtka *L.König i sin* iz Beča. Rudarilo se na tri revira: *Paulina, Marija* i *Aleksand*(er)*rija,* prema imenima Königove djece. Godine 1906. preuzima rudnik Paulina König a potom iste godine, t.t. *Asphalt Gewerkschaft "Adria"* iz Splita, te 1930. t.t. "*Ruda*" d.d. iz Splita.- Od 1949.-1950. istraživanje obnavlja *Naftaplin* iz Zagreba, a 1953. osniva se rudarsko poduzeće "*Paklina*", koje se 1961. integriralo sa specijaliziranim građevinskim poduzećem "*Izolacija*" iz Beograda čiji je, oko 25 godina, bio pogon.

Do 1961. u Paklini se rudarilo podzemno. Poslije se eksploatacija provodila površinskim kopom. Približna proizvodnja asfalta prikazana je u tablici 1.

Utvrđeno je da se poslije dužih prekida, izazvanih svjetskim ratovima, stari jamski radovi dijelom popune prirodnim bitumenom, pa se udjel kvalitetnije sirovine povremeno povećavao (sl. 4).

Cijeđenje bitumena iz pukotina i špiljskih prostora vidljivo je i danas na površinskom kopu (sl.5.)

Bitumen ispunjava prsline i druge sitnije šupljine, ali i drobivu sitnež. Ima ga manje ili više u bituminoznim vapnencima i bituminoznoj vapnenačkoj tektonskoj breči. U Paklini se rudarilo kombinacijama okana i/ili niskopa te hodnika. Pretežno se rudarilo do 50m dubine, gdje je lociran najdublji IV horizont. Niskopom (II) usmjerenim iz II horizonta na 25m do dubine 75m-80m, (prema "Izvadku iz starog rudarskog nacrta M 1:1000, koji je načinjen 12.6.1945.g. u Splitu", a nalazi se u arhivi "Saveznog geološkog zavoda" u Beogradu) dosegnuta je najveća dubina s podzemnim rudarskim radom u Vrgorcu. Najdublje vertikalno okno nalazi se u reviru Paulina, duboko je 55m, dok dubina "vjetrenog" ili zračnog okna na rudnom polju Aleksandrija iznosi 40m.



Antonio Barbaro
dal 1667 al 1671
Libro I
di Carte 426

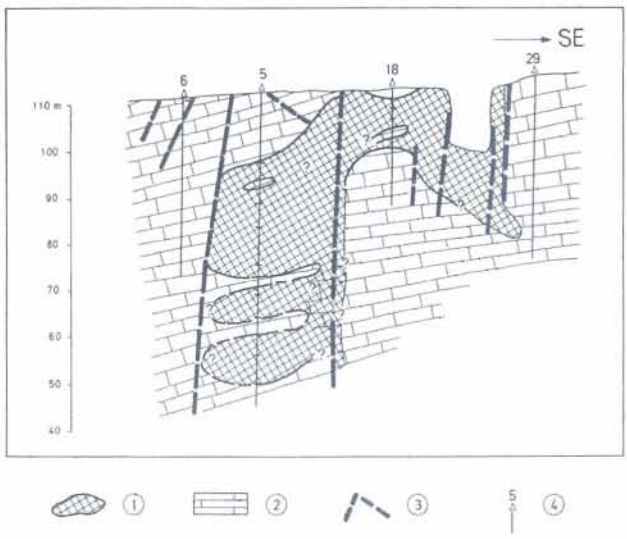
Sl. 6. F. Zanetini/Ravetini prema S o l d u, 1978/i B. Calomati dobili su 16.11.1668. odobrenje za iskapanje asfalta u jednom rudniku u Dalmaciji i Albaniji u jurisdikciji J. Sortija (B a r b a r o, 1670). Odobrenje se odnosilo za otvaranje rudnika pakline (pegole) na brdu Vinišću, a navedeni poduzetnici pozivaju se na prijašnje iskorištavanje pakline od 27.6.1628., kad je opći providur A. Pisăni dozvolio iskapanje pakline I. Đonkalijiću (S o l d o, 1978)

Fig. 6. F. Zanetini/ Ravetini after S o l d o, 1978/and B. Calomati obtained on November 16, 1668 the approval for excavating of asphalt in a mine of Dalmatia and Albania under the jurisdiction of J. Sorti (B a r b a r o, 1670). The approval was intended for opening a bitumen (pegola) mine on the hill of Vinišće, and the mentioned entrepreneurs referred to their previous exploitation of bitumen dated June 27, 1628 when A. Pisani, Local Authority Officer, permitted the bitumen excavation to I. Đonkalijić (S o l d o, 1978)

Prema Š i n k o v c u (1957) na području bivšeg asfaltnog rudnog tijela "Aleksandar" (prije zvanog "Aleksander" i "Aleksandrija") postoje rezerve B kategorije asfaltne breče od 45260t te C1 kategorije od 30000t i to unutar i između "vjetrenog" i poprečnog okna. Šinkovec pretpostavlja da je na području nekadašnjeg revira "Aleksandar" bilo izvađeno 50000 t asfaltne breče. On zaključuje da i na području rudnih polja "Paulina" i "Marija" postoje zalihe asfaltne breče, no ta mu područja nisu bila dostupna istraživanju. Bilančne rezerve bituminoznih, odnosno asfaltnih stijena su utvrđene 86 300 t (A kategorije 16400 t, B kategorije 25100 t i C1 kategorije 44800 t) s prosječnim sadržajem 10%-18% bitumena. Procjenjene su rezerve čak i 340000 t sa 7,2% bitumena s time da 60% rezervi ima 12% bitumena (P a t r l j, 1975). Pitanje procjene većih rezervi povezano je s teškoćama u usmjeravanju budućih istraživanja, jer su rezultati prije započetih istražnih bušenja vrlo skromni.

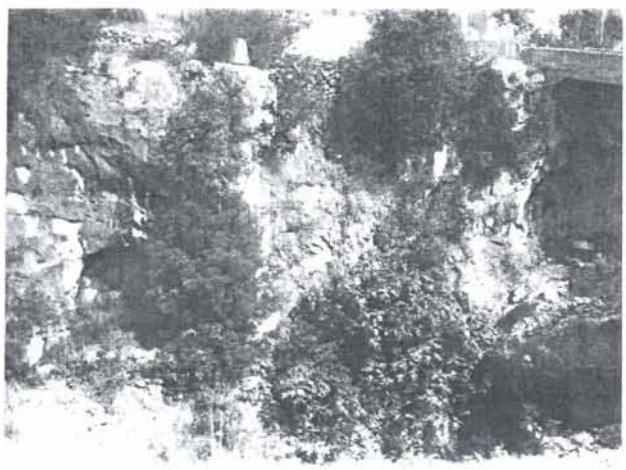
Kod Vrgorca je postojao pogon za preradu sirovine. Sastojao se od drobilane, mlina i postrojenja za pripravljanje mastiksa i izolacijskih ploča. U prošlosti s dalmatinskim asfaltom prekriveni su mnogi mostovi, terase, izolirana skladišta, rezervoari i dr. u Europi. Vrgoračkim je asfaltom 1886. asfaltirano nekoliko kristalizacijskih bazena soli u Stonu, od kojih je Sv. Mundo još pedesetih godina XX. stoljeća bio gotovo neoštećen. Njime je također asfaltiran najveći dio Sarajeva (A n o n i m u s, 1932).

U Vinišću prirodni je asfalt eksploatiran 1668. (sl. 6) ali i 1628. (B a r b a r o, 1670, S o l d o, 1978), a pretpostavlja se i ranije (Š e b e č i ć, 1984), jer je prirodni bitumen u srednjem, a dijelom i u novom vijeku rabljen za bitumenizaciju drvenih brodova. Dali je koje od naših najstarijih ležišta asfalta bilo poznato u doba hrvatskih vladara, poglavito za kneza Domagoja (IX. stoljeće), i kralja Zvonimira (XI. stoljeće), kada smo raspolagali sa snažnom ratnom drvenom flotom, može se (ne-)pouzdano hipotetizirati. Prema usmenom priopćenju pok. kolege H a n i c h a, Vinišće je mogla biti luka za popravak brodova, jer je pregledavajući fotograme u moru viniškog zaljeva primjetio ostatke stupova za privez brodova, a



Sl. 7. Vinišće-"Biskupija", profil kroz nabušene senonske vapnence. Na jugoistočnoj strani profila je stara "minera" o kojoj postoje arhivski podaci iz početka XVII. stoljeća.
(1) bituminozni vapnenci
(2) senonski vapnenci
(3) pukotine i rasjedi
(4) istražne bušotine

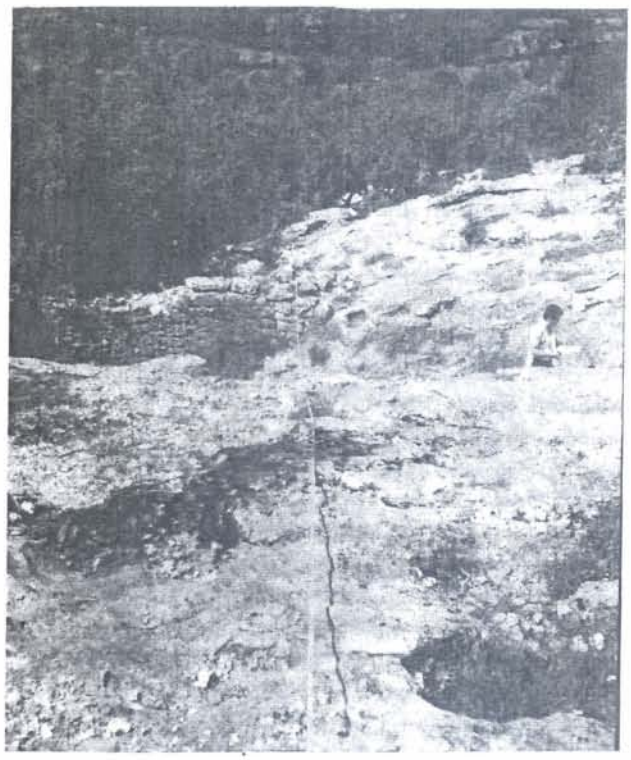
Fig. 7. Vinišće-"Biskupija", cross-section through the tapped Senonian limestones. On the south-eastern side of the section there is an ancient "minera" (mine) mentioned in the archives of the beginning of 17th century.
(1) bituminous limestones
(2) Senonian limestones
(3) cracks and faults
(4) exploration boreholes



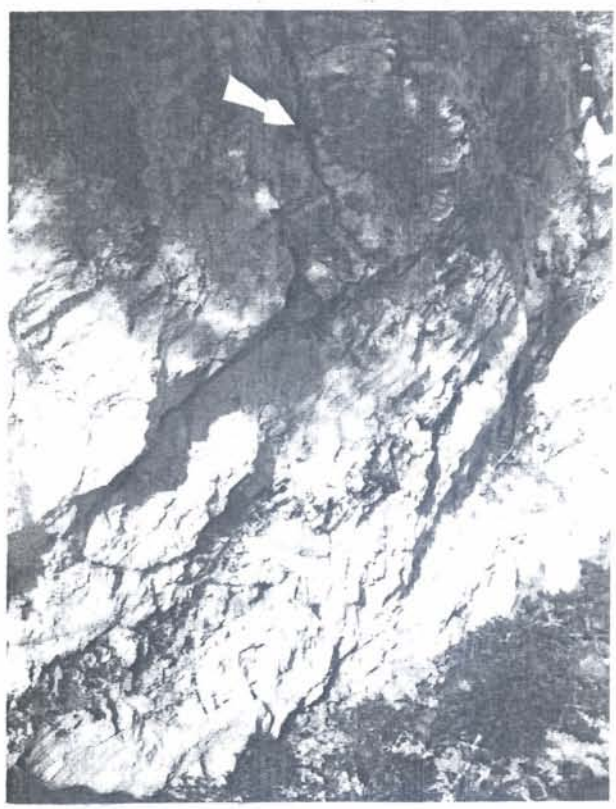
Sl. 8. Dubinski kop u ležištu asfalta Vinišće-"Opatija". Izgled njegovog sjevernog dubljeg dijela
Fig. 8. Depth pit of the Vinišće-"Opatija" asphalt deposit. A photograph of its northern deeper part

nalazišta u Vinišču su blizu mora. Kako su najstarija nalazišta prirodnog bitumena na Braču i Čiovu bila neznačajna to su nalazišta u Vinišču mogla u daljoj prošlosti imati odgovarajuće značenje, tim više što se umjetna paklina (katran) ne spominje u statutima Brača i Trogira, kao što se u srednjem vijeku, a i kasnije spominje u statutima otoka Korčule i Hvara, gdje se paklina pravila od smreke i jele, jer tamo u prošlosti nisu zabilježena nalazišta prirodnog asfalta, a potrebe za umjetnim bitumenom bile su znatne za korčulansko, hvarsko i venecijansko brodogradilište (P e d e r i n, 1991).

Vlasnici su viniških nalazišta bili *Trogirska biskupija*, prema kojem je autor nalazišta na brdu iznad Viniščа nazvao Vinišće- Biskupija (Š e b e č i ć, 1984) i *Trogirska benediktinska opatija* (Vinišće-Opatija, Š e b e č i ć, 1984). Još 1670. na opelaciju trogirskih biskupa "Vijeće desetorice" zabranilo je rudarskim poduzetnicima aktivnost na brdu iznad Viniščа, jer su uzurpirali zemljište Trogirske biskupije. Slični pokušaj je učinjen približno 175 god. kasnije nakon obnavljanja rudarske aktivnosti u Viniščу - Opatiji kada je nasljednik benediktinske opatije iz Trogira, Splitsko sjemenište, tražilo zaštitu kod trogirskog suda, koji je zabranio odvoz asfalta iz Viniščа u Veneciju, dok poduzetnik barun *Rotschild* nije kupio čestice zemlje gdje se nalazilo nalazište. Uz nalazište Vinišće-Opatija njemački *inženjer Hermann*, opunomoćenik baruna Rotschilda, postavio je nekoliko mlinova (S l a d e-Š i l o v i ć, 1939) za sitnjenje asfaltnog vapnenca te kotao, odnosno peć za zagrijavanje i "topljenje" bitumena, koji se potom cjedio u bačvice, ili su iz crne kaše pravili mastiks pogače, te kao poluproizvod ili pak samo kao sirovinu transportirali jedrenjacima od 1840, a



Sl. 9. Plitki površinski kop u senonskim biogenim vapnencima u ležištu "Paklinka" - Balovi u Primorskom Dolcu, koji se nekada zvao Suhi Dolac
Fig. 9. A shallow surface pit in Senonian biogene limestones in the deposit of "Paklinka" - Balovi at Primorski Dolac, once called Suhi Dolac



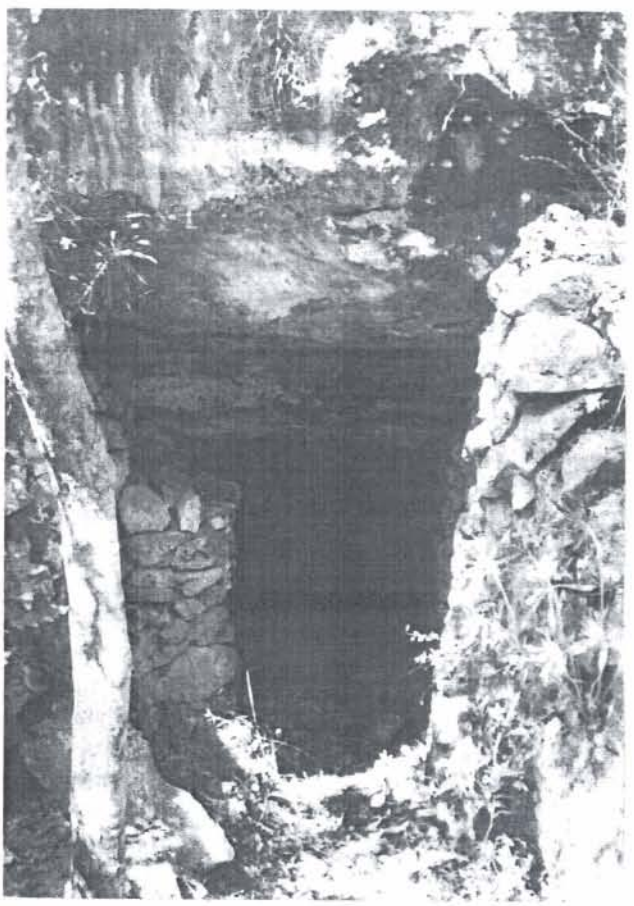
Sl. 10. Infiltracija bitumena u paleogene vapnence. "Sv. Andrija", Čiovo kod Trogira
Fig. 10. Bitumen infiltration in Paleogenic limestones. "Sv. Andrija" (St. Andrew), Čiovo by Trogir

pretpostavlja se do konca XIX stoljeća, u Veneciju i dr.

U Vinišću je, po B a u č i ć u (1943), bila prva hrvatska tvornica asfalta, koja je prestala radom prije I. svjetskog rata. Viniški asfalt, osim što je izvažan zajedno s vrgoračkim i škripskim (M a r s c h a l l, 1856) u Veneciju, a i drugdje u Italiju, zatim Austriju, Prusku i dr. (T a m b u r i n i, 1852), rabljen je i u Dalmaciji za asfaltiranje skladišta, terasa, podzemnih prostorija i dr. Sačuvan je ugovor između *E. Hartunga,* poduzetnika iz Vinišća i Financijskog ureda Dubrovnik sklopljen 5.VIII.1874. za asfaltiranje bazena soli *Sv. Frano* (Francesco) površine 845 kvadratnih klaftri, a debljine 4-5 cm. Kasnijim ugovorom od 25.V.1876. Hartung se obvezao asfaltirati kristalizaciijski bazen "*Mondo*" sličnih dimenzija, t.j. 870 kv.klaf.(3130 m^2), a za što je nakon primopredaje asfaltnog bazena naplaćeno sveukupno 5220,91 fiorina (Arhiv S l a d e - Š i l o v i ć, Trogir).

Nakon II. svjetskog rata na Biskupiji procjenjene su zalihe od 10 000 t (S i l a i Š i n k o v e c, 1955) do 25 000 t (G e m b a č e v et al., 1956), a istražnim bušenjem izračunate su bilančne rezerve od 100 206 t (Š e b e č i ć i T r u t i n, 1985) i to B kategorije 97 461 t i C_1 kategije 2745t. Potencijalne (C_2+D_1) rezerve iz tzv. "sjeverne zone", gdje nije bušeno, procjenjene su 50 337 t, tako da se svih bilančnih i izvanbilančnih zaliha procjenjuje 175 000t uz stupanj iztraženosti od 69%. Utvrđena je vrlo složena građa najvećeg bituminoznog tijela. To je nepravilno masivno do bankovito tijelo debljine 0.10m-26,20m (Sl. 7). Srednji sadržaj slobodnog toluen - bitumena najvećeg bituminoznog tijela iznosi 3,05% (79

Sl. 12. Bituminozni dolomiti u svodu jamske (rudničke) dvorane u središnjem dijelu rudnika Škrip na otoku Braču
Fig. 12. Bituminous dolomites in the ceiling of mine pit hall in the middle of Škrip mine on the Island of Brač



Sl. 11. Ulaz u rudnik Škrip na otoku Braču. Lijevo je dio ulaza u niskop obložen suhozidom od jalovih karbonatnih stijena
Fig. 11. Entry into a mine Škrip on the Island of Brač. On the left is a part of the entrance into the incline lined with dry stone walling of carbonate rocks

analiza), a gubitaka žarenjem na 550°C, s kojim je procjenjen sadržaj kerogena i vezanog bitumena, je 0.58% (76 analiza). Prosječni ponderirani sadržaj slobodnog bitumena za nabušeno područje iznosi 2,29% (130 analiza), a gubitka žarenjem 0.65% (130 analiza). Ukupno za Vinišće-Biskupiju srednji sadržaj bitumena (181 analiza) je 2,00%, a gubitka žarenjem na 550°C 0,76%. Sveukupno iz dosadašnjih 213 analiza bitumena srednji sadržaj iznosi 2,24%.

Bitumen se nalazi u porama različite geneze u senonskim biogenim vapnencima, pretežno u biomikruditima i bio(pseudo-)sparruditima, Gg-Pp-Ww-Pp-Gg vapnenačke sekvencije, koji se odlikuju boljim kolektorskim svojstvima u odnosu na podinske i krovinske vapnence-biomikrite. Osim istražnog bušenja (34 istražne bušotine dubina 20m-66,8m) provedena su i rudarsko-geološka istraživanja raskopima, potkopom te produbljenjem starog okna. Od starih rudarskih radova ističu se dvije "min(j)ere" povezane potkopom te jedno istražno okno. Iz navedenog možemo zaključiti da je na Biskupiji otkopan tek mali dio zaliha.

Bituminozno nalazište Vinišće-Opatija je dubinski kop (Sl. 8) dubine 15 m, otkopavan u tri nivoa, a s najdubljim nivoom, gdje je dosegnuta razina mora. Zbog blizine mora i obiteljskih kuća ne sugerira se na tome području obnavljanje istraživanja. Bituminozni vapnenci su po tipu biomikriti (w), a sadrže 3,04% bitumena (4 uzorka).

Od trogirskih bituminoznih nalazišta, osim Vinišća, značajni su bituminozni gornjokredni vapnenci **Balova** u Primorskom Dolcu i bituminozni gornjokredni dolomiti Ninčevića Lokve u **Radošiću**. Prvo se nalazište spominje u prošlosti pod nazivom Suhi dol (S c h u b e r t, 1909), a još ranije tj. 1804. kao Suhi Dolac, što je stari naziv za Primorski Dolac. To je plići manji površinski kop na padini brda (sl. 9) prozvan u narodu Paklinka, dok je drugo manje nalazište u Radošiću otkriveno kasnije (S c h u b e r t, 1909). Sve ostalo su manja bituminozna nalazišta uključujući i ona na Čiovu, koje je u svome putopisu vrlo detaljno opisao F o r t i s još 1774. (sl. 10).

Na F o r t i s o v opis "rudnika smolastog asfalta" na zapadnom rtu Čiova prvi je reagirao nepoznati izvjestitelj Marije Terezije (S o l d o, 1978), koji je za tu "pojavu" paklíne napisao (približno 1776.) da je odlične kvalitete, ali da se može sakupiti tek nekoliko libara, tj. dvije do tri kile (N o v a k, 1962). P e d e r i n (1991) pretpostavlja da je to tajno izvješće napisao neki čovjek iz blizine *Wilhelma Boltsa*, Nijemca rođena u Londonu, a čije su zasluge bile i osnivanje *"Triester-Ostindische Handelskompanie"* 1776. u Trstu. Nepoznati izvjestitelj prigovorio je F o r t i s u što je krivim informacijama o količini rude mletačkoj vladi sugerirao da se upusti u eksploataciju, što to ona ipak nije učinila. Zatim izvjestitelj piše da još ponešto pakline ima na jednom mjestu kraj Škripa na Braču, u jednoj uvali prije Vrgorca (nalazište Kotezi) te nedaleko Sinja (Đipalovo vrilo) i jugozapandno od Sinja.

U neretvljanskom području u podnožju brda Rabe tj. u Slivnu Fortis spominje također rudnik smolastog asfalta, s pripomenom da ga nije posjetio. Rudnik smolastog asfalta Sv. Ivan u "Pučišću" na Braču F o r t i s nije također našao, a dr. *Bajamonti* mu je pokazao uzorak s tog lokaliteta. F o r t i s je konstatirao da su fosili u tom asfaltnom kamenu drugačiji nego što je vidio u drugim asfaltnim nalazištima u Dalmaciji (F o r m a l e o n i, 1786).

Na sjevernom dijelu otoka B r a č a, nedaleko mjesta **Škrip** nalazi se napušten rudnik (sl. 11) asfalta tj. bituminoznog dolomita koji je otkopavan između 1750. i 1874. Glavni dio rudnika čini nekoliko jamskih dvorana u dolomitu koji je dijelom bio obogačen bitumenom (sl. 12). U niskopu i bočnim

Sl. 13. Odobrenje za rudarsko istraživanje ("rovna dozvola") E. Hartungu na području okružne kapetanije Split i Sinj. Dobiveno 1873., produženo 1874.

Fig. 13. Approval for mining exploration ("mining permit") granted to E. Hartung in the District of Split and Sinj by the Local Authorities in 1873 and extended in 1874.

Sl. 14. Pismo kojim J. Klaczka iz "Asphaltene" - Anonimnog (dioničkog) društva jadranskog asfalta i bitumena iz Pariza priopćava 9.1.1874 g. H. Hartungu iz Trogira da je Društvo odustalo od kupnje prava prvesnstva asfaltne rude (odnosi se na rudnik asfalta Škrip na Braču), gdje je bilo uskladišteno 400 t rude, koju nudi Društvo za prodati (smanjeni pretisak iz Arhiva S l a d e - Š i l o v i ć, Trogir)

Fig. 14. The letter of J. Klaczka (January, 9 1874) from "Asphaltene" - Anonimus Society of Adriatic Asphalt and Bitumen, Paris, by which advises Mr. H. Hartung from Trogir that the Society has waived its priority right of purchasing asphalt ore (this regards the asphalt mine of Škrip on the Island of Brač) comprising the stock of 400 t stored there and offered by Society for sale (diminished reprint from the Archive of S l a d e - Š i l o v i ć, Trogir.

Beschreibung

ALLER JENER ENTDECKUNG IM MINERALREICHE AUF MEINER REISE DURCH DAS KÖNIGREICH DALMATIEN, UND ISTRIEN
[Nota die mit roten Numern bezeihneten Örten sind vorläufig auch durch Herrn von Panz untersucht worden.][2]

Vorgefunden		haben		sich	als	
Im Districte von	Benennung des Ortes	Benennung des Minerals	Lage nach der Weltgegend	Gebirge	Giebt Hofnung auf Nutzen	Anmerkungen
(1)	(2)	(3)	(4)	(5)	(6)	(7)
8. detto	Im Signer Thale	Steinkohlen laut Bericht vom 25te 8ber 1803.	Streicher von St. 7.nach 19. und verflächen sich auf St. 1 unordentlich	zwischen Schotter und Kalkstein	diese Steinkohlenwasserläufen (?) sind 1/2 bis 3 mächtig, folglich nicht bauwürdig	diese sub Nur 6. 7, 8. und 9. angezeigte Natur-Produkte sind durch die obberüchnten Hochlöblichen von Pantz nicht untersuchet worden
10.[8]	Vergortz	Erdpech laut Bericht vom 18te Janner 1804.	Kommt am Fusse des Berges Radovich Mitternachts-seite in den Bergtrüchtenen vor	Mergel und Kalkstein	Bei dem Umstand, da das Pech aus jenne 2 in Baustehenden Bergtrichtnen grösten Theils bereidgewonnen wurde, und in Erwägung dessen, dass das Riesfallige Erdpech mit dem Kalkmergel sehr stark geschwänzert ist, giebt wenig Hofnung auf einen ergiebiegen und standhaften Bau.	Dieses Erdpech wird zu zeiten durch einen gewissen Schiffcapitain Bernardo Conparetto als Unterlenenträger betriben.
12.[9] Scbenico	Szuhidolatz	Erdhartz laut Bericht vom 25.Janner 1804.	Mitternachtseits	Im Kalkstein		Da dieses Bergthene zwischen den Spatten des festen Kalksteines bei der grossen Sommerhitze in einer sehr geringen Quantität in gestalt eines öls hereuterfliesste, so giebt gar kein Hofnung zu einen vortheilhaften Bergbau.
13.[10] Trau	auf der Insel Bua	detto detto	detto	detto		
14.[11] Narente	Bei den dorfe Slivno	Erdpech laut Bericht vom 20te Janner 1804.	gegen Mitternacht	Im Kalkstein	Nachdem in diesem Orten nach vorgenommenen lediglich das Ende einer schrotfalender(?) Kalkberge mit dem Erdpech geschwagert worden ist, so verdient es nicht als in nutzbringend Natur-Produkt angesehen zu werden	Untersuchung
19. Insel Braza	Bei Mirtze und Nyeresche	Ein mit Erdpech durchdrum yener 2 Schuch mächtiger Mergel laut Bericht von 20te November 1803.	gegen Mitternacht	Kalkmergel	Seines sparsamen vorkommen wegen unbauwürdig	Dieses Erdpech wurde noch unter der vormaligen Venetianischen Regierung bearbeitet, und als ein kein Nutzen abwerfendes Mineral Produkt aufgelassen. Wurde durch Hochlöblichen von Pantz nicht untersuchet.
22. Barbana	Sebische	Erdpech laut Bericht vom 3te Juny 1804.	gegen Mitternacht	Im Kalkgebirge	Dieses 4 Zoll mächtige mit vielen Kalkschotter gemengte weder in die Länge, und Breite, noch in die Teufe anhaltende Pech ist unbauwürdig.	Diese N° 21. 22. und 23. angezeigten Natur-Produkte sind durch den Hochlöblichen von Pantz nicht untersuchet worden. Elias Garapics K.K. Schürfungs Comissair mp.
24. Priquente	Sovignaio	Steinkohlen und Alaun laut Bericht des Horwath d.d. 21te Juny 1804. No. Aul.8188	----------	Zwischen Kalkflötzen	Die Steinkohlen sind nicht bauwürdig; der Alaun wird von einer Privat Gesellschaft benutzet.	

8545 Prl: 26 July 1804.

1354

Tabellarischer Bericht des Elias Garapits detto 20. July 1804. über Seine gebürgs Untersuchung in Dalmatien und Istrien ad acta

Sl. 15. Opisi dijela otkrivenog mineralnog blaga u Dalmaciji i Istri (prema P a n t z u i G a r a p i s c u 1804, E r c e g, 1992)
Fig. 15. Descriptions of a part mineral riches in Dalmatia and Istria (after P a n t z and G a r a p i c s, 1804; E r c e g, 1992)

hodnicima nalazi se samo mjestimično malo asfalta i to u tankim slojevima ili uprskanjima. Stoga je i razumljivo zašto se odustalo od rudarenja. Ni naknadno obnavljanje rudarske aktivnosti s dva potkopa u istočnom dijelu nalazišta, kao i plitko istražno bušenje, nisu dali pozitivne rezultate. Od starijih rudarskih radova zabilježeno je na istočnom nalazištu nekoliko raskopa.

Iz škripske rude ekstrahiran je bitumen uglavnom u dvjema okruglim pećima. Peći su razrušene, a jedna je i zatrpana. Zapadni dio nalazišta je bogatiji bitumenom (2,63%-9,40%) u odnosu na istočni (0,09%-3,19%). Na temelju 26 analiza bitumena iz 1968. izračunan je srednji sadržaj od 3,57% bitumena, a s 50 analiza među kojima ima i analiza uzoraka bogatijih s bitumenom izračunan je sadržaj od 5,94% bitumena (K a n a j e t et al., 1995).

Škripski bituminozni dolomiti te tragovi bitumena u rudistnim vapnencima, tj. bračkim "mramorima", prema J e r i n i ć u et al. 1994) pripadaju dijelu Pučišća formacije. Kerogeni stromatolitni vapnenci Mirce i Brizija na Braču pripadaju dijelu Sumartin formacije (G u š i ć i J e l a s k a 1990).

Osim u rudnom polju "*Škrip*" bituminozni je dolomit otkopavan znatno kasnije u rudnom polju "*Brač*" u **Pod Badnju**. Bituminozni se vapnenci nalaze nedaleko **Pučišća** i u **Sv. Martinu** (Sumartinu), u rudnom polju "*Dalmacija*", dijelom kod **Splitske** i

Conto

Zwischen der Direction der adriatischen Asphalt Werke zu Venedig und Andreas Grosse in Spalato

Empfang.

Monat		fl	kr	fl	kr
25. Juni 1849	Auf Anweisung des Herrn Director Schulze bei Hrn. Eugen Fell in Triest behoben	300	.		
1. Juli	Auf Anweisung des Herrn Director Schultze bei den Hrn. Morpurgo & Parente in Triest behoben	387	.		
13.	do. do. do. do.	509	.		
23.	do. do. do. do.	300	.		
3. August	do. do. do. do.	600	.		
12.	do. do. do. do.	700	.		
15. October	Auf Anweisung des Hrn. Director Schulze von den Herren Morpurgo & Parente auf Spalato gesandt, erhalten	600	.		
15.	bei Hrn. Eugen Fell in Triest behoben	500	.		
22.	Die adriatischen Asphalt Werke in Venedig gestellt eine Tratte in Latinga, per 700 fl in Banknoten, Aggio Verlust 38 fl 30 kr. ... von 700 fl abgezogen, verblieben	661	30		
22.	Die adriatischen Asphalt Werke bezahlten für Andreas Grosse eine Tratte in Latinga	208	20		
29.	... bezahlten die adriatischen Asphalt Werke in Venedig für Andreas Grosse, für ... auf Venedig ... Lenzeisengl und Bogana Spesen	634	45		
14.	Die adriatischen Asphalt Werke Venedig bezahlten für Andreas Grosse eine Tratte in Latinga	1000	.		
26.	do. do. do. do.	400	.		
30.	do. do. do. do.	1000	.		
28. December	do. do. do. do.	1518	.		
29.	do. do. do. do.	211	20	9559	55
4. Jänner 1850	do. do. do. do.	1626	.		
16.	do. do. do. do.	149	20		
9. Februar	do. do. do. do.	150	.		
27.	do. do. do. do.	27	.		
27.	do. do. do.	20	.		
27.	do. do. do.	5	20		
27.	do. do. do.	2	40		
3. März	do. do. do. eine Tratte in Latinga	20	20		
3.	Auf Anweisung des Hrn. Director Schulze, bei den Hrn. Morpurgo & Parente in Triest behoben	1800	10		
8. April	Die adriatischen Asphalt Werke Venedig bezahlten für Andreas Grosse eine Tratte in Latinga	328	.		
30.	do. do. do.	14	.		
17. Mai	do. do. do. eine Tratte in Latinga	200	.		
17.	do. do. do.	77	.		
27.	Auf Anweisung des Hrn. S. M. v. Rothschild bei den Hrn. Morpurgo & Parente in Triest behoben	1400	.		
19.	Die adriatischen Asphalt Werke Venedig bezahlten für Andreas Grosse 167 fl 30 kr in Banknoten, Aggio Verlust	140	17		
26.	do. do. do. eine Tratte in Latinga	33	.		
26.	do. do. do.	18	.		
7.	do. do. do.	22	.		
12.	do. do. do.	146	.	6188	57
	Summa der Empfänge	.	.	15748	52

Spalato am 2ten März 1852.

S. E. O.

And: Grosse

Sl. 16. Tekući račun Uprave venecijske tvornice jadranskih asfalta od lipnja 1849. do svibnja 1851.

Fig. 16. Current cost estimate by Managment of Venetian Factory of Adriatic Asphalts from June 1849 to May 1851.

Corrent.

in dem Zeitraume vom Monat Juni 1849 bis 10ten Mai 1851.

Ausgabe.

Monat		fl	kr	fl	kr
	Material Transports-Spesen.				
Juni 1849.	Laut der pro Juni 1849 [illegible] Rechnung	27	12		
Juli "	" " " Juli " dto.	138	42		
August "	" " " August " dto.	42	.	227	54
	Inventar Ankauf und Anfertigung.				
Juni "	Laut der [illegible] pro Juni 1849 [illegible] Rechnung	32	50		
Juli "	" " " Juli "	143	25 ½		
August "	" " " August "	64	35		
October "	" " " October "	127	49 ½		
November "	" " " November "	88	39 ½		
December "	" " " December "	266	52 ½		
Jänner 1850.	" " " Jänner 1850	624	6	1348	28 ½
	Bergamt Brazza.				
19. Juni 1849.	An Hrn. Director Wilhelm Schulze für selbes [illegible]	300	.		
Juli "	Laut der [illegible] Rechnung pro Juli 1849	322	10		
August "	" " " August "	470	20		
November "	" " " November "	27	20		
December "	" " " December "	241	11		
28. Februar 1850.	An [illegible] Lloyd Agenzie und k.k. Dogana, [illegible] für 2 [illegible], – welche Herr Eugen Hell aus Triest [illegible], – bezahlt	3	18	1364	19
	Porto Mandoler.				
August 1849.	Laut der [illegible] Rechnung pro August 1849.	100	.		
October "	" " " October "	100	.		
November "	" " " November "	130	.		
December "	" " " December "	100	.		
Jänner 1850.	" " " Jänner 1850.	100	.	530	.
	Grubenbetrieb zu Vergoracts.				
December 1849.	Laut der [illegible] Rechnung pro December 1849.	.	.	300	.
	Besondere Auslagen.				
Juli 1849.	Laut der [illegible] Rechnung pro Juli 1849.	176	30		
August "	" " " August "	2	.	178	30
	Direction des Stabilemento Adriatico in Venedig.				
October 1849.	[illegible] mit Patron Michele auf Venedig versendete 634 Ctr. Massen Asphaltsteine per Ctr. 27 kr. bezahlt	285	18		
November "	[illegible] mit Patron [illegible] auf Venedig versendete 911 Ctr. 73 ℔ Massen Asphaltsteine, à Ctr. 27 kr. bezahlt	410	16 ½		
	[illegible] auf Venedig versendete 65 Ctr. 84 ℔ Brazza [illegible] per Ctr. 2 kr. [illegible] bezahlt	2	11 ½		
	[illegible] Asphaltsteine, – [illegible] auf Venedig gesendet wurden, [illegible] bezahlt	24	16		
	[illegible] pro October und November 1849 [illegible]				
November "	Laut der [illegible] Rechnung pro November 1849.	80			
December "	" " " December "	1342	25		
Jänner 1850.	[illegible], laut der [illegible] Rechnung pro Jänner 1850.	237			
	[illegible] mit Patron [illegible] auf Venedig versendete 584 Ctr. 20 ℔ klein geschlagene Massen Asphaltsteine à 29 ½ kr. per Ctr. bezahlt	287	13 ½		
	[illegible] mit demselben Patron versendete 50 Ctr. Massen Asphaltsteine in großen Blöcken, per Centner 27 kr. bezahlt	22	30		
	[illegible] mit Patron Nicolo Lazzaro auf Venedig versendete 1900 Ctr. Massen Asphaltsteine in großen Blöcken per Centner 27 kr.	855	½		
	Mit demselben Patron wurden 65 Carren Holz auf Venedig versendet, [illegible] per Carra 5 kr. [illegible] bezahlt	5	57		
Februar 1850.	An [illegible] Scarpa und Callitrona [illegible] auf Venedig, [illegible] Asphalt [illegible], bezahlt	64			
	[illegible] Contractes, [illegible] Nicolich bezahlt	5			
	[illegible] bezahlt	2			
März "	An [illegible] Scarpa und Callitrona, auf Anweisung des Hrn. Directors Schulze bezahlt	20			
April "	[illegible], auf Anweisung des Herrn Directors Schulze bezahlt	20	.		
6. " "	[illegible] mit Patron Antonio Paulo auf Venedig versendete 475 Ctr. 18 ℔ Asphalt Mastix [illegible] per Ctr. à 2 kr. bezahlt	15	50 ½		
	[illegible] mit demselben Patron auf Venedig versendete 816 Ctr. 70 ℔ klein geschlagene Massen Asphaltsteine à Ctr. 29 ½ kr. bezahlt	401	31 ½		
13. " "	[illegible] mit Patron Marco Mattera auf Venedig versendete 706 " 85 ℔ " dto. dto. dto. 29 ½ dto.	347	32 ½		
	[illegible] mit demselben Patron versendete 273 Ctr. 85 ℔ Asphalt Mastix [illegible] per Centner 2 kr. bezahlt	9	7 ½		
30. " "	Auf [illegible] des Hrn. Directors Schulze vom 29ten März 1850 an Hrn. Mattes [illegible] bezahlt. B.N.	400	.		
Mai 1850.	An [illegible] Giovanni Scarpa, auf Anweisung des Hrn. Directors Schulze, bezahlt	10	.		
8. " "	[illegible] mit Patron Andrea auf Venedig versendete 1318 Ctr. klein geschlagene Massen Asphaltsteine, à Ctr. 29 ½ kr. bezahlt	648	1 ¼		
18. " "	[illegible] mit Patron Antonio Paulo auf Venedig versendete 1016 Ctr. 9 ℔ klein geschlagene Massen Asphaltsteine à Ctr. 29 ½ kr. bezahlt	499	39		
	[illegible] mit demselben Patron auf Venedig versendete 135 Carren [illegible] Holz, [illegible] Dogana [illegible] per Carra 2 fl. 55 kr.	390	45		
30. " "	[illegible] Asphalt [illegible] bezahlt	6	.		
	[illegible]	5	20		
	[illegible] 4 [illegible] Paolo [illegible] à 25 kr.	1	40		
	[illegible] 4 [illegible] à 20 kr.	1	20		
	[illegible] mit dem Patron [illegible] für die Asphalt [illegible] bei Hrn. [illegible], bezahlt	4	.		
	[illegible] bezahlt	.	54		
	An [illegible] Nicolo Ventura, auf Anweisung des Hrn. Director Schulze [illegible] Salde [illegible] bei Hrn. Carl [illegible] bez.	10	.		
	Latus.	6218	19 ¼	3949	11 ½

Ausgabe.

Monat		f	kr	f	kr
	Translatus	6318	19¾	2939	11¼
30. Mai 1850.	An die Aufseher Carl Andel und Mistro Cusmanich für [illegible] Asphalt Applications Löffel, [illegible] 1 [illegible] bezahlt	30	16		
	[illegible] bezahlt	8	47		
	An den Schiffspatron Giovanni Mattulich für 3 Ladungen [illegible] von der Brazza auf Spalato zu führen, [illegible] December 1849, Jänner und Mai 1850 laut Note bezahlt [illegible] Andrich [illegible]	15			
Juni 1850.	An die Angehörigen des Maurers Giovanni Scarpa, auf Anweisung des Hr. Director Schulze bezahlt	10			
	Für mit Patron Spiridione [illegible] auf Venedig versendete 877 Ztr. 11 lb Asphaltsteine in großen Stücken, per Ztr. 27 kr bezahlt	394	40½		
6. " "	Für mit Patron Patinich auf Venedig versendete 623 Ztr. kleingeschlagene Asphaltsteine à 29½ kr per Zentner bezahlt	305	18½		
Juli 1850	An die Angehörigen des Maurers Giovanni Scarpa, auf Anweisung des Hr. Directors Schulze bezahlt	10			
	An den Bergmann Simon Dundak für [illegible] zu Crive Dolaz, bezahlt	78	40		
	Für 3 [illegible] verwendet in derselben Grube	8			
	Für mit Patron Antonio Fack auf Venedig versendete 1140 Ztr. kleingeschlagene Asphaltsteine per 29½ kr bezahlt	560	20		
	Für mit demselben Patron auf Venedig versendete 136 Carren [illegible] Holzes, mit [illegible] Legname [illegible] Kosten per Carra 3 f 4 kr bezahlt	417	54		
27. August 1850	Für mit Patron Antonio Fack auf Venedig versendete 1423 Ztr. 23 lb Asphaltstaub per Ztr. mit [illegible] 40 kr bezahlt	948	49		
	Mit demselben Schiffspatron für auf Venedig versendete 114 Ztr. 65 lb kleingeschlagene Asphaltsteine à 29½ kr bezahlt	56	22		
	Demselben Patron für auf Venedig versendete 46 Ztr. Asphaltsteine in großen Stücken à 27 kr per Zentner	20	42		
2. September "	An Andreas Grosse für 700 Ztr. Asphaltsteine auf der Grube zu Crive Dolacz [illegible] Spalato [illegible] Direction [illegible] per Zentner 10 kr	116	40		
10. Mai 1851.	An Andreas Grosse für 773 Ztr. 20 lb kleingeschlagene Asphaltsteine, welche mit Patron Giovanni Ruskovich auf Venedig versendet wurden, per Zentner 29½ kr	380	14¾		
	Für die mit demselben Patron auf Venedig versendeten 70 Ztr. Asphaltsteine in großen Stücken à Ztr. 27 kr	31	30		
	Mit demselben Schiffspatron für auf Venedig versendete 60 Ztr. Mandoler Asphaltsteine per Ztr. 2 kr	2			
	Da diese Ladung in Venedig von der Direction der Dalmatischen Asphalt Werke nicht [illegible] wurde, so mußte [illegible] dem Patron Ruskovich bezahlt werden, mit	300			
	Für die von Venedig mit eben dieser Ladung zurückgekommenen Asphaltsteine, [illegible] Locale der hiesigen Anlage zu [illegible], laut Fachinage bezahlt	36	6	10049	49
	Gruben Regie.				
December 1849.	An die k.k. Berggerichts Substitution in Sebenico laut [illegible] bezahlt [illegible]			49	40
	Mastix Erzeugung und Versandt desselben.				
Juni 1849.	Laut der [illegible] Rechnung pro Juni 1849 . . . 370 Ztr. à 25 kr	154	10		
Juli "	do. Juli . . . 750 . . 25	401	52		
August "	do. August . . . 357 ½	177	38½		
September "	do. September . . . Ztr. 1622 ⅓ . 400 . . 40 kr	466	7¾		
October "	do. October . . . 182 . . 20 kr	157	31½		
November "	In diesem Monate [illegible] 700 Ztr., bloß 200 Ztr. 33 lb Mastix verfertigt, per Zent. 50 kr	166	56½		
	[illegible]	23	15		
December "	Laut der bereits eingesendeten Rechnung pro December 1849	2	23	1559	54½
April 1850.	Für mit Patron Marco Mattera [illegible] auf Venedig [illegible] Ladung Mastix [illegible] 273 Ztr. 83 lb [illegible] 199 Ztr. 80 lb [illegible] für 74 Ztr. 3 lb [illegible] à 50 kr per Zentner	61	41½		
	Für mit Antonio Fack [illegible] auf Venedig [illegible] 475 Ztr. 18 lb Mastix [illegible] per Zentner à 50 kr	295	59		
	Für mit Patron Antonio Malvasia an Hr. Eugen Hell auf Triest versendete 400 Ztr. 3 lb Mastix, [illegible] per Ztr. à 52 kr	346	41½		
Juni 1850.	Für an die k.k. Genie Direction in Pola versendete 312 Ztr. 21 lb Mastix [illegible] per Ztr. 50 kr	260	10½		
	Für an das Franciscaner Kloster zu Sign versendete 22 Zentner Asphalt Mastix [illegible] à 50 kr per Ztr.	26	40		
August 1850.	Für an die k.k. Genie Direction zu Spalato abgegebene 340 Zent. do. do. do. à 50 kr per Ztr.	283	20		
	[illegible] in Spalato [illegible] abgegebene 109 Ztr. 64 lb do. do. do. à 50 kr	91	22		
	Für von der Brazza in den Monat Jennaar und Mai 1850 [illegible] 126 [illegible] 136 Ztr. 47 lb laut Fachinage, [illegible] Marine [illegible] Anlage [illegible], à Ztr. 2 kr bezahlt	4	33		
	An Andreas Grosse für 44 Ztr. [illegible] per Ztr. 10 f	440		1910	27
	Zusammen die Ausgabe			17519	2
	Der Empfang beträgt mit			15748	52
	[illegible] Andreas Grosse [illegible]			1770	10

Spalato am 2ten März 1852.

S. E. C.

Mirce. Kerogeni vapnenci, odnosno "fosilni ugljeni" otkopavani su u rudnim poljima "*Wilhelm*" južno od Mirce, "*Gustav*" i "*Herman*" na sjeverozapadu Brača, te u **Kolačima** jugozapadno od Nerežišća i u rudnom polju "*Austrija*", južno od **Dračevice** na jugozapadu Brača. Kerogenih vapnenaca ima još kod Bola, Zečeva, Postira i Sutivana (J e l a s k a et al., 1983).

Sve rudarske koncesije (T o m a š i ć, 1949) dobivene za Austro- Ugarske bile su na snazi i za Kraljevine Jugoslavije, što ukazuje na nekadašnji interes za ekaploataciju i primjenu kako bituminoznih tako i kerogenih stijena. Potrebno je istaknuti da navedena nalazišta nisu detaljno geološki istražena, bez obzira na stupanj njihovog rudarskog istraživanja, pa je teško procjeniti njihove rezerve.

Sredinom XIX. stoljeća proizvodio se u Škripu prirodni asfalt s 9%-10% bitumena, te izvozio teretnim jedrenjacima zajedno sa vrgoračkim i viniškim asfaltom u Veneciju (M a r s c h a l l, 1856), gdje je prerađivan kao sirovina ili poluproizvod. Proizvodi dobiveni preradom prirodnog asfalta iz Dalmacije bili su prikazani na *Pariškoj izložbi* 1855., gdje je bilo prisutno 30 izlagača iz Francuske, Austrije, Bavarske, Španjolske, Portugala Kanade i Meksika.

Povlasticu za kopanje bračkih, a i viniških asfalta dobio je u drugoj polovicu XIX. stoljeća *Heinrich (Enrico)Hartung*, poduzetnik iz Trogira, podrijetlom iz Njemačke. To se obznanjuje u dozvoli za rudarsko istraživanje temeljeno na austrijskom rudarskom zakonu iz 1854., a odnosi se na kapetaniju Split i Sinj, a koju je H a r t u n g pribavio 1873. (sl. 13), te produžio 1874. Sačuvan je njegov certifikat iz 1879. za slobodno istraživanje (asfalta) u Vinišću.

Prema N i k o l i ć u (1900) bračka nalazišta u Sv. Martinu, Mirci, Škripu, Splitskoj i Nerežišću istraživali su rudarski inženjeri "*Steinkohlen-Gewerkschaft-a*" već 1840. god. Od svih nalazišta najviše je obećavao Škrip. No, unatoč visokoj proizvodnji od 120.10^3 bč.c (6735 t) u četiri godine škripski je rudnik došao u teškoće, pa je banka prepustila rudnik privatnicima. Godine 1873. rudnik je zakupila frncuska "*L' Asphalteine, Societe Anonyme des Asphaltes et des Bitumes de L' Adriatique*", ili "*Asfaltena*, Dioničko (Anonimno) društvo za jadranske asfalte i bitumene", iz Pariza od *E. Hartunga* iz Trogira. Naime, iz dokumenta kraljevskog i carskog bilježnika dr. *A. Hochkoflera* iz Trsta od 15.1.1874 može se zaključiti da se Hartung obvezao prodati "Asfalteni" koncesiju za istraživanje asfalta. Kako Hartung vjerojatno nije potpisao ugovor, jer ga se opominjalo, pretpostavlja se da je "Asfaltena" uvidjevši složenu rudarsko-geološku situaciju u škripskom rudniku odustala od kupnje prava prvenstva korištenja asfaltne rude, a za iskopanih 400 t moli Hartunga da asfalt ostane uskladišten, dok se nađe kupac (sl. 14).

Od asfaltnih nalazišta na Braču S ö h l e (1900) najviše opisuje Škrip, čija se debljina dolomitnog "pijeska" bogatog s asfaltom maksimalno procjenjuje oko 20m.

Prema P e r i č i ć u (1980), *G.Billio*, vjerojatno podrijetlom naš Bilić (op. Šebečića) geolog-istraživač, ali i rudarski poduzetnik, otkrio je ugljen kod Skradina, na Promini (Siverić, Dubravice i Velušić), a fosilni ugljen na Braču (Smirče), gdje je otkrio i paklinu. Prema D i e d i (S o l d o, 1978) *Billio* je dobio s *D. Stressijem* 1782. investituru vađenja fosilnog ugljena u cijeloj Dalmaciji. Tako je *Billio* počeo iskapati fosilni ugljen, tj. kerogene stromatolitne vapnence na zemlji Smirče (kod Mirce, op. Šebečića) dva kilometra jugoistočno od Sutivana, odakle su ih odvozili teretnim jedrenjakom u Rafineriju šećera u Rijeku. U pismu svome posredniku *P.Bergaliću, Billio* ističe

RUDARSKA INSPEKCIJA - SPLIT
Broj: 1369 god. 1931.

Svjedočanstvo prijave samorova

Rudarska inspekcija u Splitu potvrdjuje ovim, da je gosp.
BANSKA VLAST BANOVINE HRVATSKE - ODJEL ZA RUDARSTVO
ZAGREB
na temelju rovne dozvole od 15. siječnja 1940. broj 54
podneskom prikazanim dne 10. travnja 1941. prijavio samorov u
poreznoj općini DOLAC DONJI; poreznog kotara OMIŠ,
srez SPLIT, banovina HRVATSKA.

Polazna točka tog samorova nalazi se od trigonometrične točke A 454 »GRABOVAC« na 3630 metara udaljeno u pravcu prema 16 hora, 8 grada, 0 minuta, 0 sekunda po astronomskom meridijanu.

Znak samorova biti će postavljen neposredno kod rovne jame

Samorovac je obavezan, da tačno ispunjuje propise Rudarskog zakona od 23. maja 1854, a osobito da podnaša po čl. 178. tog zakona propisane polugodišnje izvještaje o preduzetim istražnjim radnjama. (Za I polugodište do 15. jula iste godine, a za II. polugodište do 15 januara slijedeće godine).

Samorov traje samo za vrijeme trajanja navedene rovne dozvole.

Samorovna pristojba uplaćuje se po propisima Pravilnika za naplaćivanje pristojbi za samorove od 11. XII. 1928. R. Broj 12259/28.

Split, dne 10. travnja 1941.

Rudarski inspektor:

Sl. 17. Svjedočanstvo o prijavi samorova u Dolcu Donjem
Fig. 17. Certificate on the registration of mining at Dolac Donji

da je početkom 1791. god. bilo u Sutivanu uskladišteno oko 12 vagona, t.j. 114t "ugljena".

Godina 1784. i 1785. *M.Šimunović* i *N.Šimunović* te *I.Srempić* i *M.Beroš* dobili su od Magistrata dozvolu za iskapanje pakline iz triju "rupa" u Martinici ili Smriči.

Godine 1781. *A.Lovrić* iz Sinja zajedno sa *V.Celio-Cega* (S o l d o, 1978) dobili su dozvolu za vađenje crnog asfalta na rtu **Sv.Ciprijana** kod Trogira uz plaćanje desetine.

O pojavi mrlja smole (kao katrana) na brdu Humu nedaleko od benediktinskog samostna i crkve kod **Komiže** na Visu izvijestio je pismom 1782. god. Ekonomsko društvo u Splitu liječnik *Barbijeri,* te istakao da narod zove to mjesto Paklenica i da se tu kopa katran (tj. paklina), koji se rabi za mazanje ribarskih brodova (Ž g a l j i ć, 1984).

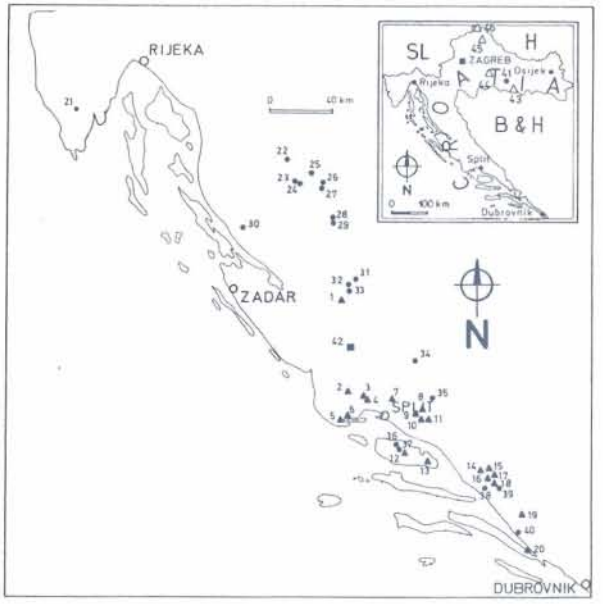
Godine 1786, dobila je obitelj M o s c a t t i pravo kopanja asfalta kod **Siverića**, međutim zbog velikih gubitaka odustala je od daljeg kopanja po isteku dozvole (P e r i č i ć, 1980).

Nakon propasti Mletačke Republike, Istra i Dalmacija ušle su u sastav Austrijske Monarhije, pa je njena Hofkammer (Dvorska gospodarska komora) registrirala do tada poznato rudno blago na navedenom području. Tabelarno izvješće ovih istraživanja (sl. 15) načinili su P a n t z i G a r a p i c s (1804), što gotovo poslije 190 god. spominje E r c e g (1992). Ukupno su opisali 26 lokaliteta od kojih je 7 sa zemnom smolom i to "Barban" u Istri, Suhi Dolac, Vrgorac, Slivno na Neretvi, te Čiovo i Brač (Mirca i Nerežišće). Zemna smola, odnosno bitumen nalazi se u vapnencima, a ponegdje u vapnenačkim laporima. Za većinu su pregledanih lokaliteta P a n t z i G a r a p i c s utvrdili da nisu vrijedni; nadalje za nalazište Slivno su konstatirali da ne služi kao korisni prirodni produkt, dok su za nalazište Vrgorac pretpostavili da ima malo nade za izdašniju eksploataciju, što je kasnije demantirano. Za bračka nalazišta su istaknuli da su iztraživana već za venecijanske vladavine.

Od mosorskih bituminoznih ležišta prvo se spominje ležište u Dolcu (H a u e r, 1850), odnosno u **Krivom Dolcu** (S c h l e h a n, 1851), gdje su bili izvođeni veći rudarski radovi, čiji su troškovi od 1849. do 1851. zapisani u tekućem računu (sl. 16).

Iz tekućeg računa što je načinjen između "*Direction der adriatischen Asphalt Werke zu Venedig*" i *Grossa*(1852) iz Splita vidljivo je da su ukupni primici iznosili 15748,52 fl., a izdaci 17519,2 fl. U izdacima navode se među inim i oni što ih je načinilo Rudarsko nadleštvo na Braču (1364,19 fl.) i Vinišću (530 fl.) te u rudarskom pogonu u Vrgorcu (300 fl.). Najveće troškove učinilo je "Upraviteljstvo tvornice za preradu asfalta u Veneciji" tijekom dijela 1849., u 1850. i u dijelu 1851 god. na mosorskom asfaltnom području uključujući Krivi Dolac (≈4967 fl.).

Potom su R i t t e r et al, (1855) pisali o jamama sjeveroistočno od Splita, vjerojatno na dolačkom području, koje su nazvane "*Alleanza*" (Savez), "*Fedelta*" (Vjernost), "*Fiducia*" (Pouzdanje) i "*Madonna delle Grazie*" (Gospa od milosti). Kasnije K e r n e r (1916) opisuje asfaltna nalazišta i ležišta i u Donjem Dolcu: Okruglicu, Putišća Stan, kasnije nazvane "Staje", Na Privaj, zatim Gornja Rošca i



▲ ① • ② ■ ③ △④

Sl. 18. Karta ležišta i značajnih nalazišta bituminoznih i kerogenih stijena

Fig..18 Map of deposits and major occurrences of bituminous and kerogenous rocks

(1) bituminozna ležišta i nalazišta *(bituminous deposits and occurrences):*
1-Čanci(?B), 2-Suhi Dolac (Primorski Dolac)-"Balovi(B), 3-Radošić- "Lastva pod Glavicom"(B), 4-Radošić-"Ninčevića lokva"(B), 5-Vinišće- "Opatija"(B), 6-Vinišće-"Biskupija"(B), 7-Prugovo (?B), 8-Gornja Rošca (BK), 9-Na Privaj-"Mišetin Dolac" (B), 10-Donji Dolac- Okruglice"(B)+"Krivi Dolac"(B), 11-Nova Sela-"Bradarić"(B), 12- Brač-"Škrip"(B), 13-Brač-"Pod Badanj" (?B), 14-Kozica(B), 15-Vranješi (BK-B), 16-Majići(B), 17-Vrgorac-"Grljušići(B), 18-Vrgorac-"Paklina" (BK-B), 19-Solarevina (BK-B), 20-Gnjili Rat (?B)

(2) kerogena ležišta i nalazišta *(kerogenous deposits and occurrences):*
21-Trlji(K), 22-Plitvice(K), 23-Vrelo Koreničko "Zubovića Draga"(K), 24- Vrelo Koreničko-"Mrsinj Grad" ("Milanovića Draga")(K), 25-Baljevac(K), BiH, 26-Zavalje(K), BiH, 27-Bijela Greda(K-BK), BiH , 28-Donji Lapac- "Mamac"(K), 29-DonjiLapac- "Opačić Draga"- (K), 30-Brušane(K), 31-Poštak- "Vagan"(K), 32-Poštak-"Dimići" (K-BK), 33-Poštak-"Mijina Glava"(K), 34- Vrdovo-"Golo Brdo(K), 35-Sinj-"Ruda"(K), 36-Brač-"Mirca" (B,K), 37-Brač- "Brizi" (K), 38-Vrgorac-"Orlić" (?K?B), 39-Vrgorac-"Plana" (?K), 40-Kremena-"Bakića kuće"(K), 41-Novska-Paklenica (BK)

(3) ugljeviti sedimenti *(carbonaceous sediments)*: 42-Siverić-"Okumpava"(K)

(4) nafta-bitumen *(crude oil)*: 43 Bačindol, 44-Mikleuška, 45- Veliki Poganac, 46-Peklenica

Akrap, a kasnije (1919.) Župu, Kozicu, Drežnicu, Štikovo, Radošić i dr.

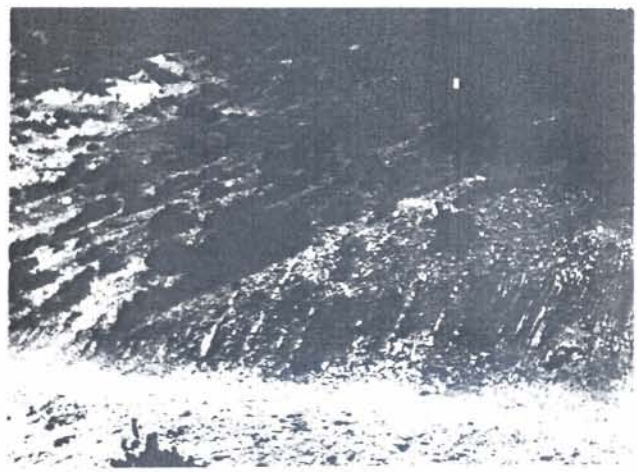
Rudno polje "Fedelta" u Krivom Dolcu podijeljeno je 1847. *Cerineu* i *Grossu* a potom vjerojatno prodano 1850. *Rougieri* . Od 1930. vlasništvo je *"Ruda" d.d.* u Splitu. Obližnja rudna polja *"Virginia"* i *"Paul"* u **Okruglici** bila su od 1904. vlasništvo *"Bergwerkgesellschafta"* iz Hamburga, a od 1930. bili su u zakupu *ing. Grochowalskog,* nekadašnjeg upravitelja vrgoračkog rudnika.

U **Gornjim Rošcima** (Donji Dolac) i **Akrapu** (Bisko) koncesiju za istraživanje, prema usmenom priopćenju mještana, imali su *Vidović* i *Sisgoreo* iz Splita. U Dolcu Donjem, t.j. Krivom Dolcu rudarska istraživanja je financirala i Banska vlast Banovine Hrvatske (sl. 17).

U Gornjim Roščima bili su sprovedeni istražni radovi raskopima te manja eksploatacija dubinskim kopom. Istražnim je bušenjem utvrđeno da se bitumen nalazi u gornjokrednim, ali i eocenskim vapnencima i tektonskim brečama. Nadalje, utvrđena je dubinska veza između bliskih površinskih izdanaka. Debljina je bituminoznih tijela prosječno 17,7m. Sadržaj je bitumena uglavnom viši u površinskim izdancima nego u nabušenim naslagama.Kvalitetnija je sirovina debela samo 1,5-6m, a tek izuzetno 16m. Za sve nabušene naslage srednji sadržaj bitumena iznosi 0,76% (70 analiza), dok je za jednu bušotinu viši, tj. 1,62% (27 analiza) (Š e b e č i ć, 1981.). Srednji sadržaj procjenjene netopive organske tvari je 1,88% (70 analiza iz 6 bušotina) (Š e b e č i ć, 1977.). Prema odnosu slobodnog bitumena u ukupnoj organskoj tvari u gornjokrednim vapnencima učestaliji su slabo kerogeno-bituminozni vapnenci, a u paleogenim vapnencima slabo bituminozno-kerogeni vapnenci i slabo kerogeni vapnenci. Procjenjeno je da je samo 10% rezervi kvalitetnija sirovina, tj. 26285 t (Š e b e č i ć, 1977.).

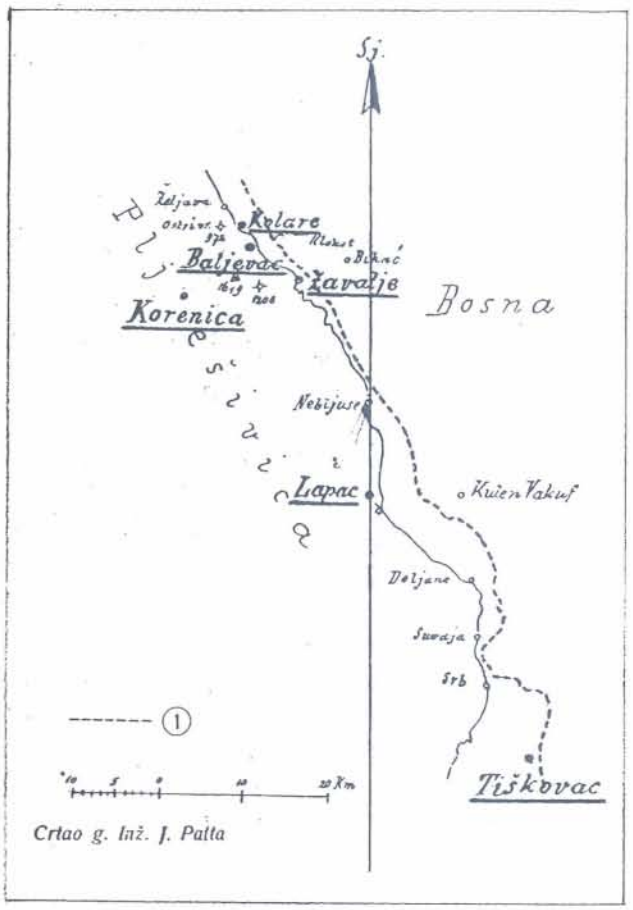
U sklopu prikaza bivših jugoslavenskih, uključivši dalmatinske asfalte A b r a h a m (1960) izdvaja vrgoračke, bračke i morovićke asfalte sa starim analitičkim podacima, dok u crnogorske krivo uvrštava ili mu je tako sugerirano, dubrovačke, viniške, čiovske i suhodolske (sjeverno - trogirske) asfalte, te asfalte između Drniša i Knina. Abraham piše da morovićki slabo dolomitizirani vapnenci iz okolice Šibenika sadrže 10-15% asfalta, dok viniški kristalični vapnenci 9,2%, a dubrovački (vjerojatno gnjilo-ratski) vapnenci 13,9%. - Naziv asfaltnog lokaliteta Morović ili Morovice vjerojatno potječe od imena sela Mokro na granici između šibenskog i trogirskog kotara (S t o š i ć, 1941), a pripada župi Danilo-Biranj.

Da je nalazište asfalta u **Gnjilom Ratu** na poluotoku Pelješcu bilo istraživano, ako ne i eksploatirano u XIX. stoljeću, dokumentirano je analizom bitumena od "vjerojatno" 25% (T r i n k e r, 1868). Prema kemijskim analizama (J o h n i E i c h l e i t e r, 1901) asfaltni vapnenci "Poljica" (D. Dolca)



Sl. 19. Pločasti i laminarni neogeni kalcitni lapori, Sinj-"Ruda". Desno je ulaz u potkop koji je sada zatrpan

Fig. 19. Tabular and laminated Neogene calcite marls, Sinj-



Sl. 20. Karta glavnih ličkih kerogenih ležišta.
(1) je dio nekadašnje granice između Hrvatske i Bosne i Hercegovine (R e i t t e r, 1926)

Fig. 20. Map of the Lika Region kerogenous deposits of major importance.
(1) is a part of the former border between Croatia and Bosnia- Herzegovina (R e i t t e r, 1926)

sadrže 32,94% bitumena, a Vrgorca 31,05%. Kasnije je u vrgoračkom asfaltu određeno 16,32% bitumena (Eichleiter i Hackl, 1920).

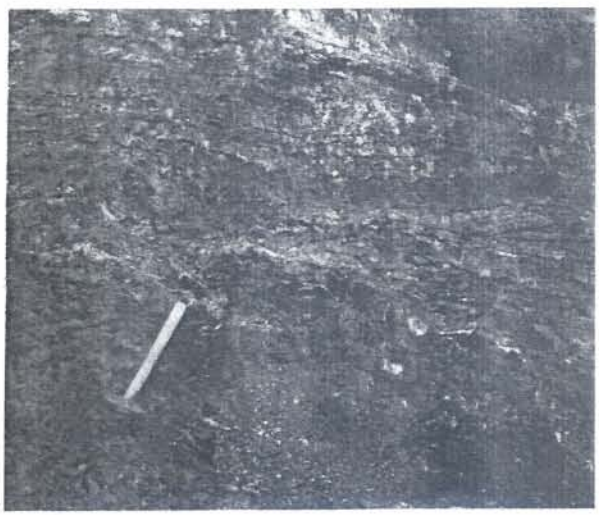
U **Kozici** su istraživani gornjokredni bituminozni dolomiti još prije I. svjetskog rata. U njima su locirana 2 niskopa po 25 m dužine. Sadržaj bitumena varira od 0,90%-11,20% (x=3,87%, N=20), a debljina bituminozne zone od 1,5 do 3 m.

Kao najznačajnije nalazište asfalta u nas Schubert (1909) navodi Vrgorac, koji je već poznat u XVIII. stoljeću, zatim Kozicu, Dolac, Radošić, te Suhi dol, Prapatnicu i dr., a na Braču: Mirca, Pučišće, Sv. Martin i Škrip. To su sve gornjo kredna ležišta i nalazišta, od jurskih nalazišta navodi Štikovo, Kijevo i dr., a od eocenskih Pelješac i Čiovo.

Na kraju, ostaje još nerješeno pitanje podrijetla okruglastih sekundarnih nakupina pakline (bitumena) u naplavinama na **Paklenim otocima**. Za sada je neutemeljeno uobičajeno povezivati izdanke pakline sa nazivom Paklenih otoka (Žgaljić, 1994), jer je kopanje pakline na Paklenim otocima nepoznato hvarskim ribarima. Činjenica je da su ribari rabili okruglaste naplavine veličine jabuke, a ponekad i veće, i da se one nalaze raspršene po uvalama, znatno više na sjevernoj strani otoka nego na južnoj. Prema usmenom priopćenju N. Gazzaria, dipl. ing. brodogradnje, podrijetlom sa Hvara, "grudaste" naplavine su donošene morskim strujama i to s maestralom sa sjeverozapada (Čiovo i/ili Vinišće-Opatija) ili jugom s (jugo-)istoka (iz doline Neretve, ili bliže s istočnog dijela Hvara). Osim toga podrijetlo ovih naplavina ne isključuje se povezati s nekim manjim podmorskim nalazištem bitumena ili nafte, što bi trebalo ispitati.

Istočno od Novske, a osobito između potoka **Paklenica** (sl. 18) i Voćarac, registrirano je više nalazišta bituminoznih slabovezanih pješčenjaka, odnosno pijesaka (Šebečić i Bulić, 1983). Debljina im je milimetarska do maksimalno nabušenih 1,35 m. Na temelju geoloških profiliranja, raskopavanja, zasjecanja i prospekcijskog istražnog bušenja konstatirano je da su bituminozne naslage volumno podređene, jer se izmjenjuju s jalovim naslagama. Tako u bušotinama omjer jalovine i rude varira od 4:1 do 15:1. Sadržaj bitumena u neogenskim Banatica naslagama Paklenice varira od 0,10% do 10,12% (x=3,76%, N=37).- Geološke rezerve između 3 bušotine su procjenjene na 50000 t, a predviđaju se da su i veće (Oreški i Đurđanović, 1983). S obzirom na tankoslojevitost i ustrmljenost bituminoznih naslaga, te nepovoljan njihov odnos prema jalovim naslagama, a uz to i neizbježnu devastaciju šuma, ne sugeriraju se dalja istraživanja na tom području.

Prema Anonimusu (1920), sjeveroistočno od **Bačindola** (sl. 18) prema Cerniku nađene su prilično laka nafta i smola u nekoliko rudarskih okana. To je ponukalo grupu poslovnih ljudi: *grofa Erdödya,*



Sl. 21. Kerogeni čertovi iz gornjojurskog ležišta Vrelo Koreničko-"Zubovića Draga", Lika
Fig. 21. Kerogenous cherts from the Upper Jurassic deposit of Vrelo Koreničko-"Zubovića Draga" at Lika

baruna Gruttschreibera i sisačke trgovce da sagrade tvornicu mineralnih ulja radi dobivanja kolomasti za podmazivanje kola i kočija.

U Paklenici kod **Mikleuške** (sl. 18), gdje je također podignuta 1860. tvornica kolomasti i kod **Volodera** na padinama Moslavačkog gorja nađena je zemna smola u tercijarnim sedimentima. U većem nalazištu u Paklenici dnevno se eksploatiralo više centi zemne smole i ulja pomješanih s vodom iz okana dubine 45-60 m. Kasnije je, 1905., društvo "Vesta" bušenjem utvrdilo zemnu smolu i na 70 m dubine, a zemni plin i na većim dubinama. Kod Volodera, 4 km zapadno od Mikleuške utvrđeno je na dubini četvrtog metra, nalazište bituminoznih stijena debljine 4-6 m., iz kojeg kaplje tamnozelena nafta.

Kod **Velikog Poganca** (sl. 18) bušenjem su u škriljavcu otkrivene gnjezdaste nakupine zemnog voska, koji se topi na 70°C. To je nalazište otkriveno nakon potresa 1882., međutim potom izvedena istražna bušenja nisu dala pozitivne rezultate.

U svom "Mineraloškom leksikonu" piše Zepharovich (1859) da se u Hrvatskoj nalazi paklina i u međimurskoj Peklenici (sl. 18) i to u tercijarnom pijesku na obali jednog potoka i u jednom 3,9 m dubokom oknu. To je ponovio i Raukar (1932) navodeći da je tamo 1836. dobivano tamnosmeđe zemno ulje za kolomaz.

Kerogena ležišta i nalazišta

"Uljni" ili kerogeni sedimenti nalaze se u Hrvatskoj na više lokaliteta u Dalmaciji, Lici, Istri i dr. (sl. 18). Iz njih se nekada dobivalo sirovo ulje u Rudi kod Sinja i Baljevcu kod Bihaća, a pretpostavlja se i u Brušanima kod Gospića. Ulje se primjenjivalo u različite svrhe: medicinske, energetske i dr. Prema dosadašnjim spoznajama može se zaključiti da se najkvalitetnija sirovina eksploatira u Rudi kod Sinja

te u Vrelu Koreničkom i Baljevcu. Istraživanjem većine nalazišta konstatirano je da se kakvoća sirovine većine lokaliteta može primnjeniti u niskoenergetske svrhe.

Naknadnim istraživanjem kerogenih nalazišta utvrđeno je da je manji dio sirovine kvalitetan, jer se u njima izmjenjuju jalovi i kerogeni dijelovi naslaga. To znatno smanjuje bilančne zalihe nalazišta. Dosadašnjim istraživanjem nisu registrirani debeloslojeviti i izrazitije kerogeni sedimenti.

Od hrvatskih ležišta uljnih škriljavaca najznačajnije se nalazi u Sinju-Ruda, (sl. 19), jer je bogato uljem (30-40%), a rezerve mu se procjenjuju "nekoliko" milijuna tona (L u k o v i ć, 1936). Drugo ležište je **Baljevac** s više tankih slojeva do 0,5m, koje je eksploatirala kraće vrijeme, tj. 1901-1905., kemijsko-farmaceutska firma "*G. Hell*" iz Troppaua (R u d a r s k o s a t n i š t v o Zagreb, 1893-1901) te iz njega dobivala "ihtiol". "Za pojave uljnih škriljavaca" u Hrvatskoj konstatira E r c e g o v a c (1990) da su na niskom nivou istraženosti, jer nedostaju podaci o organsko-petrografskim i geokemijskim svojstvima. To se prije svega odnosi na pojave Trlji i Šaini u Istri, zatim na Poštak u Lici te na Svilaju i Ruda u Dalmaciji. Smatra da bi "pojave" na Poštaku i Rudama trebalo detaljnije proučiti, jer im je kerogen sapropelnog tipa.

Pretpostavlja se da je istraživanje uljnih škriljavaca u Lici započelo u XIX. stoljeću, jer se njihova prerada obavljala u Baljevcu 1901-1905. Prema prijevodu njemačkog teksta nepoznatog autora (A n o n i m u s, ?) može se zaključiti da je za eksploataciju podjeljeno 5 koncesija: "Baljevac" (vlasnik *ing. J.Patta*, R e i t t e r, 1926;) "*Zavalje*", "*Vrelo*", "*Lapac*" i "*Korenica*" sveukupne površine 51 400 000m^2. Za Liku su navedene rezerve od 20 000 000 t.

U Baljevcu eksploataciju donjokrednog "uljnog škriljavca" pred II. svjetski rat izvodilo je "*Ličko rudarsko udruženje*" a potom i "*Gyrodal*"- rudarsko udruženje iz Zagreba. Postojala su 4 manja radilišta na kojima se radilo površinskim kopom, ali i kombinacijom niskopa i prečnika dužine nekoliko metara. Ekstrakcija ihtiol ulja obavljala se u 8 retorti na temperaturi od 520°C/3 h iz zdrobljenog uljnog škriljavca veličine oraha. Dnevna produkcija ulja iz baljevačkog ležišta bila je 1,60t-1,92t ili maksimalno 700t/god.

Iz zavaljskog, tj. suhodolskog ležišta, koje je eksploatirano kombinacijom zasjeka, potkopa i hodnika, pridobivano je 0.2t- 0.8t/dnevno odnosno 180 t ulja / god. (1947.), a iz međudražkog ili bjelogredskog 0.4t-0.5t/dan. Nedostaju podaci o produkciji iz koreničkog nalazišta, gdje su istražni radovi obavljeni s dva potkopa dužine 12m i 6m. "Škriljavci" su prerađivani u tvornici ulja u Baljevcu, koji je nakon II. svjetskog rata pripao Bosni i Hercegovini. Stara je destilerija porušena u II. svjetskom ratu, ali je nakon rata obnovljena te radila kraće vrijeme punim kapacitetom. Eksploatacija škriljavaca provodila se površinskim kopom, a otkopavalo se i u Hrvatskoj, i u Bosni i Hercegovini unutar ihtiolske dolomitne zone.

U **Vrelu Koreničkom** su dva nalazišta gornjojurskih kerogenih stijena: Zubovića Draga i Mrsinj Grad (Milanovića Draga), koja su rudarski istraživana za Austro-Ugarske na prijelazu stoljeća. Kratko su vrijeme eksploatirana nakon II. svjetskog rata, do zaključno 1949. god. Prije deset godina obnovljena su geološko-organsko-kemijska ispitivanja, kako koreničkih tako i zavaljskih, nalazišta kerogenih stijena (Š a b a n i Š e b e č i ć, 1984, Š e b e č i ć et al., 1990 b i dr.), a ispod Mrsinj Grada obavljeno je prospekcijsko istražno bušenje (S t o i s a v l j e v i ć et al., 1988). Utvrđeno je da se sadržaj organske tvari mijenja vertikalno i lateralno (0.06%-6.57%, izuzetno do 68,42% u"kerogencu", a što se moglo ilustrativno uočiti i po donjim toplinskim vrijednostima nabušenih kerogenih stijena Mrsinj Grada (od 0 do 17.401 kJ/kg, x=1986, 10 kJ/kg; 52 uzorka iz 7 bušotina, Š e b e č i ć et al. 1989).

Budući je energija znatna stavka (40 %) u proizvodnji cigle učinjen je 1989. pokušaj utvrđivanja tehno-ekonomske ocjene prve industrijske primjene "uljnih škriljavaca" u Hrvatskoj: u sirovinu za proizvodnju cigle u ciglani u Zagrebu miješano je 5% pa 10 mas.% "uljnog škriljavca", tj. mase kerogenog dolomita i kerogenog čerta iz ležišta Zubovića Draga kod Vrela Koreničkog (sl. 21).

Preliminarnim industrijskim ispitivanjem s (3%-5%) "uljnog škriljavca" s donjom toplinskom vrijednosti 1421 kJ/kg, te s industrijskim ispitivanjem s 10% "uljnog škriljavca" s donjom toplinskom vrijednošću 1250 kj/kg proizvedene su šuplje blok cigle 250x190x140 mm marke 10 i 15 (JUS D1.015). Ekonomskom analizom temeljenom na cijenama iz siječnja 1988. izračunato je da je "uljni škriljavac" kao dodatak rentabilno koristiti kada bi imao donju toplinsku vrijednost 3767 kJ/kg (Š e b e č i ć et al., 1989). Tome bi zadovoljio tek manji odabrani dio "uljnog škriljavca", pa se prekinulo s rudarsko-geološkim istraživanjima. Tek kraći transport do bliže ciglane, npr. u Perušiću, možda bi zadovoljio primjenu niže energetskih uljnih škriljavaca.

Na **Poštaku** u Lici kerogene su naslage registrirane na južnom, zapadnom i sjevernom krilu brahisinlinale koju je J a k i ć (1984) fotogeološki okonturio. Pružanje kerogenih naslaga je 17km, a debljina im je 30(-50)m. To su gornjojurski kerogeni vapnenci - biomikriti a rjeđe fosiliferni mikriti i čertovi u izmjeni, te dolomiti. Samo su područja **Dimići** i **Vagan** nešto bogatija s organskom tvari. Tako npr. sadržaj_C_{org} u uzorcima Dimića varira od 1,93% do 7,12% (x=4,38% za 19 uzoraka).

Rezerve prema *T a n c i g u* iznose 2 000 000t (Č u b r a n i ć-A j d u k o v i ć, 1981) i to na području Rastićeva, odnosno Mijine Glave gdje su 1949. obavljeni istražni radovi radi otvaranja površinskog kopa. Na bogatije predjele s organskom tvari i to Lisinu (Dimići) i Viline Plećine (Vagan) ukazao je već P e t u n n i k o f f (1938), te procjenio prevelike rezerve bituminoznih škriljavaca za cijelo nalazište (900 000 000t). Poštak je veliko nalazište, ali uglavnom niskokvalitetne sirovine.

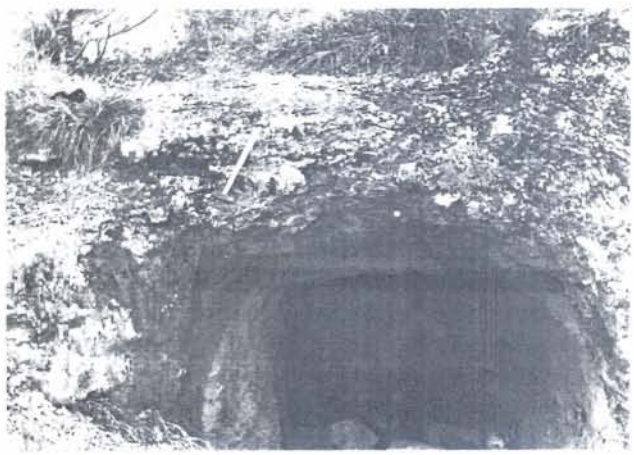
Kerogeno nalazište u **Vaganu**, zaseoku G. Tiškovca u Lici, poznato je već od prije II. svjetskog rata (P e t u n n i k o f f, 1938). To su gornjojurske Lemeš naslage, uglavnom slumpirani i laminirani dolomiti s kvarcnim nodulama. Sastavni su dio kerogenih leća kojih se dužina procjenjuje na 10-12m. U leći ima i kerogenih siltita s radiolarijama. Slobodnog bitumena ima više u dolomitu (5,24%) nego u siltitu (0,67%). Ukupno organske tvari u analiziranom dolomitu ima 49,38%.

I. Ulrich, mjernik i rudarski poduzetnik iz Sv. Jurja u Štajerskoj bio je prijavio istraživanja i rudarenja u Lici, pa je dobio rovne i samorovne dozvole u Gospiću (Brušani, Medak, Smiljani), Perušiću (Kosinj), Gračacu, Donjem Lapcu i Srbu. Nakon određenog vremena (12.XI.1882.) *Orešković* iz "Kraljevskog rudarskog satništva" iz Zagreba poslao je upit "Kraljevskom kotarskom sudu" u Zagrebu da po dotičnim općinama izvidi, da li je *Ulrich* rudario? Također je, istog datuma, poslao upite i "Kraljevskom poreznom uredu" u Gospiću, Gračacu i Otočcu da izvidi je li je *Urlich* platio samorovne pristojbe, a poglavito zaostatak za III. četvrtinu 1882. god. Iz jedinog sačuvanog odgovora iz Gračaca moglo se zaključiti da tamo Ulrich nije rudario.

Istraživanjem fosilne faune u Dalmaciji M a r g e t i ć (1952), je utvrdio da postoji više horizonata "taložnih bituminoznih (t.j. kerogenih op. Šebečića) stijena" gornjojurske, donjokredne, gornjokredne i tercijarne pripadnosti. Time je osporio starije mišljenje bečkih geologa da porijeklo asfalta treba isključivo tražiti u gornjojurskim pločastim vapnencima. Ambijent tvorbe mezozojskih (kerogenih) naslaga po M a r g e t i ć u (1952) je morski, starije tercijarnih naslaga brakičan a mlađe tercijarnih jezerski. Š a h n a z a r o v (1941) već je ranije uočio razlike u genezi bituminoznih stijena Brača, pa uz prirodne asfalte ističe i pirobituminozne stijene kako ih kasnije M a r g e t i ć (1952), a i potom K r a n j e c et al. (1964) nazivaju, taložno- "bituminozne" stijene, a nalaze se u dva horizonta, dok se prirodni asfalti nalaze između njih. Za Bračke taložno- bituminozne stijene K r a n j e c et al. (1964) zaključuju da su zbog svoje veće plastičnosti unutar debelouslojenih vapnenaca sekundarno poremećeni tj. mikroborani, mikrorasjedani i drobljeni. Pretežno se odlikuju finoslojevitom, kasnije nazvanom laminiranom strukturom, u kojoj se naizmjenično redaju karbonatni i bituminozni slojevi. U bitumenu je mikroskopski utvrđena izmjena svjetlijih i tamnijih listićavih tvorevina te "nepravilna pjegasta nagomilavanja te sitnije crne točkice nejasna porijekla" (kerogen, op. Š e b e č i ć a). Uočena je i migracija svjetlijeg bitumena u žilice i mrežaste nakupine, ali i u romboedarske pore u dolomitima.

Prema M a r g e t i ć u (1952) intenzivno se rudarilo u 1950. i 1951. na Braču (**Brizi i Dujićevo**), Drežnici (**Mir/i/lović Polje**), **Biteliću** te u **Vrdovu** i **Uništima**. U paleogenim gornjo kozinskim kerogenim vapnencima, t.z. "bituminoznim laporima" **Plane** (kod Vrgorca) izrađen je potkop 120 m i nekoliko plitikih okana. U **Antunovićima** su izdubljena dva okna dubine 2-7 m.

Prema Schle(c)hanu (F o e t t e r l e, 1851) u krovini glavnog ugljenog podinskog sloja kod



Siverića, u jami Barbara, nalaze se bituminozni laporoviti škriljavci, ali ih autor ne spominje.

Ustanovljeno je da smrdljivi "bituminozni škriljavac" tj., kerogeni vapnenac iz **Kremene** u blizini Neretve sadrži 52,7% pepela. Destilacijom je iz njega dobiveno 23%-26% katranskog ulja (A n o n i m u s, 1873).

Tablica 2.
Table 2.

Bituminozna ležišta *(bituminous deposits)*
Najveće udaljenosti između istražnih radova
Greatest distances between exploratory works

skupina ležišta *group of deposits*	udaljenosti u m *distances in m*		
	kategorija A *category A*	kategorija B *category B*	kategorija C_1 *category* C_1
prva (first)	15	30	60
druga (second)	10	20	40
treća (third)	5	10	20

Sl. 22. Ulaz u potkop u slabo kerogenim vapnencima, Barban- Rebići, Istra
Fig. 22. Entry into the adit in weak kerogenous limestones, Barban- Rebići, Istria

U tercijarnim sedimentima otkriveni su uljni škriljavci u **Rudama** i tu je prema T u ć a n u (1925) osnovan rudnik 1898. god. Plinara u Splitu rabila je te uljne škriljavce za dobivanje rasvjetnog plina i katrana. Nakon II. svjetskog rata nakratko su obnovljena rudarsko-geološka istraživanja te dijelom izračunate rezerve 3,5 milijuna tona s time da su industrijske rezerve procjenjene na 2,3 milijuna tona (Š e f, 1956). Proračun dijela rezervi za južni dio sinklinale temeljen je na rezultatima 4 bušotine te na površini 1500m x 500m, a debljini rudnog sloja od 2,4m, pa su izračunane rezerve od 1800000 m^3 sirovine. Analizom 4 uzorka jezgri po Fischerovoj metodi određeno je od 6,7% do 18,7% ulja (x=12,5% ulja). T a k š i ć je 1948. za Rudu kod Sinja procjenio ukupne rezerve "ugljena", tj. "uljnih škriljavaca" na 360000t, međutim, on smatra da je najmanje 25% rezervi izvađeno, pa je ostalo još 270 000t. Po nepovoljnijoj varijanti izračunato je samo 100 000t sirovine te je uz izvađenih 25% preostalo samo 75 000t. Navodi mišljenje rudara *A. Polaske* po kome je ugljeni sloj u rudniku bio debeo oko 1m, te da su postojala 4 horizonta koja su povezana niskopom. "Bituminozni škrilja(va)c" Ruda predstavlja po P e t r u n i ć u (1951) "prvoklasan objekt s dobrom amortizacijom". Naime, pri tome je mislio na primjenu "škriljca" u cementnoj industriji.

Od starih rudarskih radova u Rudama nije ostalo ništa pristupačno, jer su oni zarušeni ili zatrpani, kao što je ulaz posljednjeg potkopa zatrpan tik uz seoski put (sl.19), a gdje je izmjerena 5m debela zona obogaćena organskom tvari u kojoj se uzmjenjuju tamnije i svjetlije lamine. Tamnije lamine su bogate kerogenom, dok su svjetlije njime siromašnije, ili ga gotovo ne sadrže. Organska je tvar nezrela, pa se ove stijene isključuju iz naftno-matičnih stijena (Š e b e č i ć i E r c e g o v a c, 1983). Na dijelu kerogene zone u Rudama izgrađen je sada veliki ribnjak što dijelom smanjuje mogućnost eksploatacije. Nadalje, zbog ustrmljenosti slojeva i nedefinirane dubine zalijeganja postavlja se pitanje ekonomičnosti i obnavljanja eksploatacije tog kerogenog ležišta.

Od kerogenih nalazišta na **Dinari**, ističu se ona na **Golom Brdu** kod **Vrdova.** Istraživana su pedesetih godina ovog stoljeća (M a r g e t i ć 1952, F i l j a k, 1951), a posljednji put su istraživana prije nekoliko godina (Š e b e č i ć i S l o v e n e c, 1990). Njihovo značenje je zasada više sedimentološko, naftno-geološko i mineraloško nego ekonomsko. Oko 200t sirovine prerađeno je u tzv. majlerima u Sinju do 1951. i dalo je ulje dobre kvalitete. Kakvoća sirovine kerogenih stijena ocijenjena je i po gornjim toplinskim vrijednostima. Tako je utvrđeno, da je kvalitetnija sirovina (od 2500kJ/kg 4800 kJ/kg) uglavnom vezana za kerogena nalazišta 2 i 3, tj. za stromatolitne karbonatne stijene.

Kerogeno nalazište **Trlji** u Istri otkriveno je za francuske okupacije Istre, a otkopavano po Talijanima s istražnim oknima dubine 7m i 8m između dva svjetska rata. Istraživanja su obnovljena tek unazad 10 godina (V u č k o v i ć i S r n i ć, 1983, Š e b e č i ć et al. 1990). To su cenomanski kerogeni, dijelom stromatolitni, vapnenci debljine od 2-3cm do 70cm u vapnenačkoj zoni debljine 5m. Utvrđen je vrlo varijabilan sadržaj pirolizirane organske tvari (0.43%-20,74%, x=6,31% od 12 uzoraka) te varijabilan sadržaj gornjih toplinskih vrijednosti (92 kJ/kg-6338 kJ/kg, x=2143 kJ/kg od 7 uzoraka).

Tablica 3.
Table 3.

Kerogena ležišta (Kerogenous deposits)
Najveće udaljenosti između istražnih radova
Greatest distances between exploratory works

skupina ležišta *group of deposits*	udaljenosti u m *distances in m*		
	kategorija A *category A*	kategorija B *category B*	kategorija C_1 *category* C_1
prva (first)	90	180	360
druga (second)	60	120	240
treća (third)	30	60	120

U **Rebićima,** 5,5 km južno od Barbana u Istri, nalaze se gornjokredni slabo kerogeni vapnenci s 0,19%-0.66% ukupne organske tvari (x=0.34%, N=9) i mjestimično s malo bitumena. Pirolizu organske tvari na 550°C/10 min., kojom je procijenjen sadržaj ukupne organske tvari, te pirolizu organske tvari na 350°C/20 min., kojom je procjenjen sadržaj bitumena načinio je *B. Štipak*, kem. tehn.

Prema izvješću *Garapicsa* i *Pantza* iz 1804. (E r c e g, 1992) ispravno je zaključeno da postojanje "smole" u dubini ne bi naplatilo muku oko kopanja rudače, ali je neispravno zabilježen naziv nalazišta "Sebische" umjesto "Rebische" stoga je ono palo u zaborav, pa nije naznačeno na "Osnovnoj geološkoj karti" list "Labin" (Š i k i ć et al, 1969). Ipak ostao je očuvan potkop (sl. 22) pretpostavlja se od prije 150 do 200 godina, dimenzija 5,5m x 1,6m x 1,85-1,05m. U njemu se nalaze turonski pločasti vapnenci sa sitnim kerogeniziranim foraminiferama. U vapnencima ima kerogenih pjega veličine 0.05-1mm u mikritnoj osnovi fosilifernih mikrita i biomikrita. Tragove bitumena sadrže uzorci uz rasjede. Organska-kerogena tvar nalikuje ugljenu, a nalazi se pretežno kao prevlake po stijenkama pukotina. Godine 1927. pokušali su Talijani obnoviti istraživanja kopajući raskop, ali bez uspjeha.

Nova saznanja iz rudarsko-geoloških istraživanja bituminoznih i kerogenih nalazišta

Na temelju dosadašnjih spoznaja o rudarsko-geološkim istraživanjima bituminoznih stijena u Dinaridima Hrvatske autor predlaže da se u "Posebnim kriterijima za utvrđivanje i razvrstavanje rezervi pojedinih čvrstih mineralnih sirovina"

Tablica 4.
Table 4.
Rezerve bituminoznih stijena i njihova kakvoća
Reserves Bituminous Rocks and their Quality

Ležišta i nalazišta *Deposits and occurrence*	Rezerve (t) *Reserve* utvrđene *established*	potencijalne *potential*	Sadržaj bitumena *Content of bitumen* (%) (N)	Org. tvar nakon ekstr. bit. *Org. matter after extr. of bit.* (550°C/lh/(%),(N)
ČANCI		4000	6,89 (2)	
VINIŠĆE-"Biskupija"	100206	50337	2,24(213)	-
"Opatija"		20000	2,00(181) 3,04 (4)	0,76(181) -
PRIMORSKI DOLAC -"Balovi"		83685	3,10(4)	0,93(4)
RADOŠIĆ-"Ninčevića Lokva"		11710	5,46(4) 5,44(9)	1,34(4)
-"Lastva pod Glavicom"		3870	3,95(5)	- 0,67(5)
PRUGOVO		2000	12,65(4)	-
NA PRIVAJ				
-"Mišetin Dolac"		20000	3,82(4)	1,20(4)
-"Matovčeve Staje"		2000	7,51(2)	-
DONJI DOLAC				
-"Okruglice"		18000	3,52(3)	1,11(3)
"Krivi Dolac			13,34(1)	1,30(1)
NOVA SELA-"Bradarić"		10000	7,68(2)	2,55(2)
KOZICA		15000	2,33(7)	0,57(7)
VRANJEŠI		30000	3,28(4)	2,08(4)
MAJIĆI		4000	4,83(2)	1,69(2)
VRGORAC-"Paklina"	86300	600	20,0(3)	10,40(3)
"Grljušići"		15000	3,05(2)	1,24(2)
SOLAREVINA		5000	2,12(2)	1,23(2)
GNJILI RAT		5000	14,6(2)	-
BRAČ-"Škrip		15000	4,91(45)	-
-"Pod Badanj"		10000	3,90(2)	-

(N) broj analiza *(no. of analyses)*

Tablica 5.
Table 5.
Rezerve kerogenih stijena i njihova kakvoća
Reserves Kerogenous Rocks and their Quality

Ležišta i nalazišta *Deposits and occurrences*	Potencijalne rezerve *Potential reserves* (t)	Sadržaj bitumena *Content of bitumen* (%) (N)	Organska tvar *Organic matter* /C_{org}/(%),(N)
TRLJI	100 000	0,55 (19)	7,29(16)
PLITVICE	50 000	3,42 (5)	12,51(5)
VRELO KORENIČKO	2 856 000		
-"Mrsinj Grad"(Milanovića Draga")	285600 kvalitetnije sirovine	0,2 (3)	2,14(3)
+	*of which better quality*		
-"Zubovića Draga"		3,06(12)	31,42(12)
BALJEVAC	1 500 000	6,41(1)	58,07(1)
ZAVALJE	1 000 000	0,55(23)	5,49(23)
BIJELA GREDA	500 000	0,25(7)	6,60(7)
DONJI LAPAC			
-"Mamac"	100 000	0,62(5)	9,27(5)
-"Opačić Draga"	100 000	0,48(9)	6,70(9)
BRUŠANE			
- horizont II	50 000	-	4,09(5)
POŠTAK	-	1,91(31)	4,34(30)
-"Mijina Glava"	2 400 000	0,39(4)	4,05(4)
-"Dimići"	1 000 000	1,88(3)	3,22(3)
-"Vagan"	15 000	5,24(1)	70,11(1)
VRDOVO-"Golo Brdo"	390 725	6,99(21)	-
SINJ-"Ruda"	270 000	11,83(20)	32,25(6)
BRAČ-"Brizi"	60 000	3,33(6)	7,54(6)
- "Mirca"	3 000	2,55(1)	19,75(2)
VRGORAC			
- "Orlić"	5 000	-	-
- "Plana"	30 000	-	-
KREMENA			
- "Bakića kuće"	5 000	2,95(1)	19,91(1)
- "Ljubića Potok"	3 000	2,20(1)	17,38(2)
Rezerve bituminozno-kerogenih stijena i njihova kakvoća *Reserves of Bituminous - Kerogenous Rocks and their Quality*			
GORNJA ROŠCA	262 845 26 285 kvalitetnije sirovine *of which better quality*	1,38(63)	1,16(63)
NOVSKA."Paklenica"	50 000	3,76(37)	-

(N) broj analiza *(no. of analyses)*

"Pravilnika o prikupljanju podataka, načinu evidentiranja i utvrđivanja rezervi mineralnih sirovina te o izradi bilance tih rezervi" (N a r o d n e n o v i n e, 1992) odvoje bituminozne od uljnih tj. kerogenih stijena.

Bituminozna nalazišta u skladu s Pravilnikom moguće je podijeliti u tri skupine s obzirom na različit stupanj infiltracije i impregnacije stijena ugljikovodicima, odnosno bitumenom. U prvu bi se skupinu uvrstila nalazišta s 300 x 10^3t bituminozne stijenske mase, drugu skupinu sa 100-300 x 10^3t i treću sa <100 x 10^3t bituminozne stijenske mase. Podjela u podskupine je moguća, ali tek nakon opsežnih rudarsko-geoloških ispitivanja. Za istraživanje bituminoznih stijena predlaže se najdulji razmak između rudarskih istražnih radova prema tablici 2.

Budući da nije definiran udio pojedinih kategorija u ukupnim rezervama, predlaže se da rezerve A+B kategorije čine 60%-75% ukupnih rezervi, od toga A kategorija 2/3 A+B rezervi, a C_1 kategorija 25%-40%.

Za računanje p o t e n c i j a l n i h rezervi (C_2, D_1 i D_2 kategorije) treba prethodno izračunati koeficijent produktivnosti detaljno istraživanog područja (bilanciranog A+B+C_1 kategorijama rezervi), kao i odnos bituminoznosti površina kojima se procjenjuju kategorije potencijalnih rezervi i (ukupne) bituminoznosti površina koje su detaljno istraživane kao korektivnom faktoru za procjenu rezervi.

Prema sadašnjem stupnju istraženosti, koji je uglavnom nizak, jer se uglavnom temelji na procjeni potencijalnih rezervi, većina prospektiranih, ili pak dijelom ispitanih nalazišta bi spadala u treću skupinu nalazišta. U drugu skupinu bi spadalo nalazište

Vinišće-Biskupija, a u prvu skupinu pretpostavlja se Vrgorac-Paklina, ukoliko se sljedećim rudarsko-geološkim istraživanjem utvrde veće rezerve.

Ovisno o kakvoći sirovine, tj. poglavito sadržaju bitumena moguća je upotreba bituminoznih stijena. Za cestogradnju je povoljan viši sadržaj bitumena >5%, tj. 6%-10% ili 7,5%-12,5%, dok sadržaj bitumena za punilo praktički nema donju granicu. Sadržaj bitumena 1%-2% u stijeni predlaže se kao uvjetno bilančnu kakvoću, a >2% kao bilančnu kakvoću.

Kerogene, odnosno uljne stijene svrstavaju se također u tri skupine, s neophodnom pripomenom. Ako se u njima nalazi I tip (sapropelni) i II tip (sapropelno-humusni) kerogena tada su to "uljni škriljavci", a nalazi li se u njima III tip (humusni) kerogena to su "ugljeviti škriljavci".

U kerogenim stijenama kerogen može biti manje ili više jednoliko koncentriran u cijeloj stijeni. To su homogeni uljni škriljavci (u nas su rijetki). Kerogen se najčešće nalazi u laminiranim ili tankoploćastim naslagama u izmjeni sa slično takvim ali "jalovim" dijelovima s vrlo malo kerogena ili bez njega, ili se nalazi u slojevito-lećastim nakupinama. Prema veličini među našim kerogenim nalazištima treba razlikovati prvu skupinu s ukupnim rezervama više od 3×10^6t kerogenih stijena, drugu skupinu sa 3×10^5t-3×10^6t i treću skupinu sa $<3 \times 10^5$t kerogenih stijena. Kerogena nalazišta Poštaka, pretpostavlja se, mogla bi npr. uvrstiti u prvu skupinu, Vrdova-Golo Brdo u drugu skupinu, a Brača-Brizi u treću skupinu. Po dosadašnjim spoznajama samo mali dio (1/10) kerogenih stijena iz proučavanih nalazišta bi se mogao rabiti u energetske svrhe (npr. kerogena nalazišta u Vrelu Koreničkom). S obzirom na uglavnom nisku (d.) toplinsku vrijednost ispitivanih srednjih uzoraka, dijela nalazišta Mrsinj Grad u Vrelu Koreničkom (x=1986 kJ/kg od 52 uzorka) utvrđeno je da ispitane stijene mogu biti samo izvor inicijalne energije za početak gorenja (1650 kJ/kg). Zato se naši niskoenergetski kerogeni "škriljavci" mogu primjeniti samo kao punilo u asfaltnim mješavinama.

U istraživanju kerogenih stijena predlaže se najveći razmak između rudarskih istražnih radova prema tablici 3.

Ovi su razmaci znatno bliži razmacima, koji se primjenjuju u istraživanju bituminoznih i uljnih stijena (N a r o d n e n o v i n e, 1992). Za istraživanje lećastih kerogenih nalazišta primjereniji su razmaci rudarskih istražnih radova koji vrijede za bituminozna nalazišta. Isto to vrijedi i za miješana bituminozno-kerogena nalazišta (Gornja Rošca i Novska-Paklenica).

Pri geološkom istraživanju i kartiranju nalazišta s izdancima stijena obogaćenih s organskom tvari (bitumenom i/ili kerogenom) najveći geološki rizici postoje pri procjeni potencijalnih rezervi, zbog nedostatka rudarsko-geoloških radova. Ti se rizici smanjuju ulaganjem u istraživanje. Uz geološke značajni su i ekonomski rizici. Tako npr. cijena industrijskog bitumena povećava se ili smanjuje s promjenama cijena nafte na tržištu. Zato prije odluke o eksploataciji treba načiniti ekonomsku analizu koštanja dobivanja 1 t prirodnog bitumena iz asfalta i 1 t bitumena iz nafte, ili pak odrediti cijenu koštanja 1 t prirodnog punila s organskom tvari, te 1 t industrijskog punila istog sastava.

Nadalje, treba dakako ocjeniti i eksploatacijske rizike. Prvo valja spoznati da se dosadašnjim kriterijima (N a r o d n e n o v i n e, 1992) može sa sigurnošću računati na rezerve koje želimo odrediti i drugo da li s predloženim novim kriterijima o minimalnom razmaku između rudarskih istražnih radova (tablice 2 i 3) je to ekonomski opravdano, itd.

Na temelju rudarsko-geoloških i geofizičkih podataka o debljini bituminoznih ležišta i nalazišta, te debljine izdanaka, približno sam procjenio zalihe naših značajnih ležišta i nalazišta. Većina nalazišta sadrži 5-10 000 t prirodnog asfalta, a samo nekoliko nalazišta ima zalihe 80 000 t (tablica 4).

Među naša najznačajnija ležišta spadaju Paklina kod Vrgorca, Vinišće-Biskupija, Primorski Dolac-Balovi, Donji Dolac-G. Rošca i dr., gdje je svuda prekinuta eksploatacija. Neka nalazišta bi trebalo detaljnije rudarsko-geološki istražiti, kao npr. u mosorskoj bituminoznoj zoni (Donji Dolac - Okruglice i Mišetin Dolac), i u biokovskoj bituminoznoj zoni (Kozica, Vranješi i Grljušići).

Od ležišta "uljnih škriljavaca", odnosno kerogenih sedimenata, najinteresantnija se nalaze u Rudi kod Sinja i Vrelu Koreničkom (Zubovića i Milanovića Draga). U Rudi je prekinuta nekadašnja podzemna eksploatacija, dok su u Vrelu Koreničkom bila započeta, pa prekinuta. Od ostalih nalazišta u kojima su započela istraživanja, pa prekinuta, interesantna su na Braču (Brizi) i Dinari (Vrdovo), jer sadrže i povišene sadržaje organske tvari, tj. kerogena, a s time i povišene toplinske vrijednosti sirovine. Za većinu nalazišta može se zaključiti da ih je za sada neracionalno istraživati, jer sadrže uglavnom niske sadržaje organske tvari. U toj je grupi i naše najveće kerogeno nalazište "Poštak". Procjenjuje se da geološke zalihe navedenih većih nalazišta dostižu od 300 000 do 2 400 000 t, a manja nalazišta (na Braču) oko 60 000 t (tablica 5).

Pretvaranje resursa u rezerve

Uz pronalaženje novih nalazišta bituminoznih i kerogenih stijena značajno je i pretvaranje resursa u nekim nalazištima u rezerve. Do otkrića novih nalazišta dug je put. Povezan je uglavnom s rudarsko-geološkim te organsko-kemijskim i tehnološkim ispitivanjima sirovine.

Transformacija resursa u rezerve moguća je kod vrlo perspektivnih nalazišta gdje su određene uvjetno-bilančne zalihe, koje na taj način postaju bilančne, a nalazišta postaju ležišta, ili se pak nekada

napuštena nalazišta s niže kvalitetnom sirovinom reaktiviraju. Transformacija je dinamičan proces (S i n g h, 1984), a najčešće je u svezi s novim tehnologijama primjene sirovine s nižim sadržajem korisne komponente. Tako je to npr. za bituminozne i kerogene stijene i njihovu primjenu u punilima za cestogradevne sustave, a posebno za kerogene stijene ("uljne škriljavce") za njihovu primjenu za specijalna uljna maziva (E n c i c l o p e d i a i t a l i a n a, 1949), ili za njihovo sagorijevanje u fluidiziranom sloju poput nisko kaloričnih ugljena i ugljevitih sedimenata, ili pak za njihovo sagorijevanje u Sterlingovu motoru (prema usmenom priopćenju prof. *A b r a m o v i ć a)*. Nadalje, jalovišta ugljena i uljnih škriljavaca postaju zanimljiva u fertilizacijske svrhe, ali ujedno i za rekultiviranje njihovih površina u gospodarstvene svrhe i u druge namjene. Na naftnim i/ili plinskim poljima postojećim bušotinama moguće je provesti otplinjavanje nabušenih slojeva ugljena odnosno kerogenih sedimenata. Plin metan mogao bi se dobivati i iz rudnika, gdje se nalaze na pr. ugljeni, ugljeviti sedimenti i sl.

R a s p r a v a i z a k l j u č c i

Poznato je da su bituminozne stijene (prirodni asfati), i kerogene stijene ("uljni škriljavci") obogaćene s organskom tvari. U Hrvatskoj su to uglavnom karbonatne stijene: vapnenci i dolomiti, a manje pješčenjaci, siltiti, šejlovi, čertovi i dr. U njima sadržaj topivog bitumena i/ili netopivog kerogena, iz kojeg se može dobiti ulje, može znatno varirati. To se odražava na promjeni kakvoće sirovine i veličini nalazišta. Ovisno o sadržaju bitumena i/ili kerogena u ukupnoj organskoj tvari ili u stijeni moguće je ispitivanu stijenu uvrstiti u bituminoznu ("bitumenac"), ako sadrži >50% bitumena u ukupnoj organskoj tvari ili kerogenu ("kerogenac"), ako pak sadrži >50% kerogena u ukupnoj organskoj tvari. Dalju je podjelu moguće načiniti prema slici 1, s 1 ili 2 hibridne stijene, pa se može razlikovati praktična "trodjelna" podjela. Moguća je i četverodjelna podjela kao u podjeli hibridnih karbonatnih stijena (Š e b e č i ć, 1983). U skladu s time mogu se izdvojiti "kerogeni bitumenac" ili "bituminozni kerogenac".- U skladu sa S c h m i t z o v o m podjelom (1986) moguće je jednotipne organolite podjeliti na "čisti bitumen"- "bitumenac" - "bituminozna stijena" te "čisti kerogen" - "kerogenac" - "kerogena stijena".

Rudarsko-geološkim istraživanjima bituminoznih i kerogenih ležišta u Hrvatskoj došlo je do spoznaje da je potrebno posebnim kriterijima vrednovati bituminozna, a posebno kerogena nalazišta. Stoga su i razmaci između istražnih radova (tablice 2 i 3) prilagođeni kategorijama A, B i C_1 rezervi. Bituminozna nalazišta podjeljena su na tri skupine s rezervama >300 x 10^3t, 100-300 x 10^3t, i <100x10^3t, a kerogena nalazišta s rezervama >3 x 10^6t; 3 x 10^5 - 3 x 10^6t i <3x10^5t. Za istraživanje bituminozno-kerogenih i lećastih kerogenih nalazišta primjereniji su razmaci između bušaćih i rudarskih istražnih radova koji vrijede za bituminozna ležišta. Prije odluke o istraživanju i eksploataciji nekog starog nalazišta treba dobro ocijeniti ekonomske i eksploatacijske rizike.

Kako se ne raspolaže s podacima o eksploataciji prirodnih bitumena u Hrvatskoj u srednjem vijeku, već samo u ranom novom vijeku, to sva razmišljanja o mogućem dobivanju pakline u srednjem vijeku u nas poprimaju značenje bolje ili lošije hipoteze. Pretpostavljam da je bitumen dovažan iz nalazišta bliskih moru kao što je nalazište u Vinišću, zatim na otoku Braču (Pučišće i Škrip) te u blizini rijeke Neretve (Paklina). Da je Vinišće mogla biti luka za izradu i/ili popravak brodova, osim njegove povoljne lokacije između Šibenika i Splita, odnosno blizine Trogira, svjedoče ostaci stupova u moru u viniškom zaljevu.

Od davnina je zabilježena primjena prirodnog bitumena, odnosno pakline, u hidroizolaciji brodova i čamaca, u podmazivanju, u graditeljstvu, u obrambenoj svrsi pri opsjedanju utvrda gradova, u pomorskim bitkama "grčkom vatrom" i dr. Paklina se mogla koristiti iz vlastitih nalazišta, uvoziti, ili se pak umjesto nje mogao rabiti katran dobiven destilacijom drva.

Povijesni je tijek rudarenja bituminoznih odnosno asfaltnih nalazišta u Hrvatskoj dulji od 400 godina. Prema M a t t h i o l i j u (1565) možemo konstatirati da se jedno od najstarijih nalazišta u Dalmaciji nalazi u blizini ušća Neretve. Potrebno je istaknuti da se druga vrlo stara nalazišta nalaze u Vinišću nedaleko mora (sada "Opatija"), i u brdu ("Biskupija"), zatim na Braču u Škripu i dr. U Panonskoj Hrvatskoj najstarije nalazište bitumena, odnosno oksidirane nafte, zabilježeno je u Peklenici u Međimurju. Sredinom XIX. stoljeća započinju intenzivna istraživanja asfalta u mosorskom području (Krivi Dolac), a nešto prije obnavlja se eksploatacija asfalta u Vinišću ("Opatija"), kada je tu utemeljena prva "tvornica" za preradu asfalta. Vrhunac proizvodnje asfalta dosegnut je koncem XIX. stoljeća.

Eksploatacija kerogenih nalazišta, odnosno "bituminoznih ("uljnih") škriljavaca" ranije zvanih "kameni (ili "fosilni") ugljen" započela je prije 200 godina u Smirči na Braču. Saznanje o tome možemo zahvaliti našem istraživaču J. Biliću (Billio), koji je učestvovao i u istraživanju prominskih i skradinskih ugljena. Brački "kameni ugljen" je odvožen u Rijeku za potrebe riječke šećerane. "Uljni škriljavci" otkriveni su ubrzo i u Istri (Trlji), Sinjskom polju, Slivnu (Kremena), a sredinom XIX. stoljeća ponovno na Braču (Nerežišće, Splitska i Mirca). Najznačajnije razdoblje za uljne škriljavce Hrvatske povezuje se na početak njihove prerade u Baljevcu i Sinju početkom i sredinom XX. stoljeća.

O "uljnim škriljavcima", ili kerogenim sedimentima osobito se raspravlja u vrijeme energetskih kriza ili

povećanih energetskih potreba, a to je vrijeme svjetskih ratova, gospodarstvenih i političkih blokada, zatim nakon većih skokova cijena nafte i plina na svjetskom tržištu, a i pri nedostatku novih rezervi osnovnih energetskih sirovina. Razlog što se u svijetu malo eksploatiraju u tome je što ulje iz "škriljavaca" još ne može konkurirati jeftinoj nafti. Prema tome kerogeni sedimenti, kao alternativne energetske sirovine, energetski su resursi budućnosti.

Kako rudarstvo zahtijeva financijska ulaganja u istraživanje, a k tome i znatno veća ulaganja u eksploataciju sirovina, mnoga su planirana ili započeta istraživanja prekinuta jer niti u prošlosti, a i niti u sadašnjosti nije bilo odgovarajućih investitora; bolje rečeno velikih glavničara, kao što je to bio u XIX. stoljeću barun *Rotschild*, koji je nastavio već prekinute rudarske aktivnosti kao npr. u Vinišću i Vrgorcu, ili ih je sam započeo, što je slučaj s kopanjem ugljena u Siveriću i dr. Nadalje, problem je bio što domaći poduzetnici, da su i imali kapitala, nisu imali znanja za izvođenje velikih radova. Nažalost, situacija se nije bitno promijenila ni danas u XX. stoljeću. Kao izuzetak u tome može se istaknuti mjernik *A. Dešković* iz Omiša (A d r i a t i c u s, 1905) koji se uz francusko-talijanski kapital angažirao na podizanju hidroelektrane "Gubavica", kasnije nazvane "Kraljevac", na slapu rijeke Cetine u Zadvorju 1912., poučen iskustvom gradnje naše prve hidroelektrane "Krka" na rijeci Krki (Šupuk i Meichsner 1895 iz G a r i b o v i ć i M o s e r, 1995) energijom podići industriju asfalta i ugljena u Dalmaciji početkom XX. stoljeća.

U Hrvatskoj se danas ne eksploatira ni jedno bituminozno ili kerogeno ležište. Uz manje prekide za svjetskih ratova, ili istraživanja, najdulje se rudarilo na području Vrgorca u Paklini i u Vinišću na nalazištu Opatija i Biskupija. Sva su druga nalazišta manjh dimenzija i kraće su eksploatirana i istraživana. Istraživanje i rudarenje je obnavljano u više navrata, kako su se mijenjali društveni sustavi i potrebe. Od poznatih ležišta vrgoračka je Paklina eksploatirana sve do 1986. Potrebno je istaknuti da su rudarska istraživanja pretežno bila prospekcijska, dok je samo nekoliko ležišta detaljnije rudarski istraživano, a to su asfalti Pakline, Škripa, Vinišća i Donjeg Dolca, te "uljni škriljavci" Rude kod Sinja, Vrela Koreničkog i Baljevca. Izrađivana su geološka mišljenja o kronostratigrafskoj pripadnosti, položaju i načinu javljanja ležišta, procjenama rezervi, o kakvoći sirovine, a izuzetno o fizičkim svojstvima stijena, koje sadrže organske tvari. Ponegdje se raspravljalo o genezi organske tvari, a u novije vrijeme i o naftno-geološkim značajkama stijena u kojoj je organska tvar akumulirana primarno ili sekundarno.

Novijim rudarsko-geološkim istraživanjem obuhvaćeno je samo nekoliko ležišta. To su bituminozna ležišta iz trogirskog područja (Vinišće-Biskupija i Ninčevića Lokva u Radošićima), jedno bituminozno-kerogeno ležište iz mosorskog područja (Gornja Rošca u Donjem Dolcu) i jedno iz slavonskog područja (Paklenica kod Novske).

Preliminarnim kemijskim i fizičko-kemijskim ispitivanjima bitumena i stijenske mase dobiven je tek uvid u mogućnost primjene i to za punilo za asfaltne mješavine, kao dodatak za asfaltni beton, za hidroizolacijski materijal i sl., međutim prirodni asfalt, valja još detaljno tehnološki ispitati da bi se mogao optimalno iskoristiti.

S novijim rudarsko-geološkim istraživanjima kerogenih stijena, t.j. "uljnih" ili "bituminoznih škriljavaca" tek se započelo prije desetak godina kod Vrela Koreničkog na području Ličke Plešivice i kod Dimića na Poštaku, tako da je u ovom trenutku nemoguće procjeniti potencijalnost ove sirovine u Hrvatskoj za njenu moguću uporabu. Naime, prva ispitivanja pokazala su skromne rezultate u svezi kakvoće sirovine, pa se stoga možemo samo prisjetiti kako je uz staru tehnologiju "majlera", vjerojatno odabrane sirovine, dobivena određena količina sirovog ulja u Rudi kod Sinja. Povezano s time znana je i ljekovitost preparata na osnovi estrahiranog ulja iz baljevačkog,odnosno plešivićkog ihtiolskog "škriljavca".

Na temelju dosadašnjih istraživanja bituminoznih i kerogenih stijena Dinarida Hrvatske te analitičkih podataka o njihovoj kakvoći može se zaključiti da je u Dinaridima Hrvatske zabilježeno 173 ležišta i nalazišta. Od toga 42 pripadaju bituminoznim, 20 bituminozno-kerogenim, a 111 kerogenim stijenama. Po kakvoći sirovine izvršena je selekcija među navedenim lokalitetima pa je izdvojeno 30-tak ležišta, dok je većina lokaliteta svrstano u nalazišta. Od 30 ležišta 15 je bituminoznih, 13 je kerogenih i 2 su bituminozno-kerogena. Pretpostavlja se da bi tek polovina od navedenih 30 ležišta mogla biti zanimljiva za buduća rudarsko-geološka istraživanja. Veliki odnos (1:6) između broja ležišta i nalazišta kako bituminoznih, tako i kerogenih stijena odraz je vrlo promjenjive kakvoće ispitivanih sirovina. Bituminozna nalazišta u nas odlikuju se s promjenjivom koncentracijom bitumena te s manjim dimenzijama bituminoznih tijela. Zato eksploataciju bituminoznih nalazišta treba organizirati tako da se njome zahvati više nalazišta na nekom području. Traženi sadržaj bitumena postići će se miješanjem sirovina s različitim sadržajem bitumena, a po potrebi i dodavanjem industrijskog bitumena. Nadalje, potrebno je imati na umu da je ekonomski opravdana ona eksploatacija koja nije skupa, odnosno opterećena dugim transportom sirovine do mjesta primjene. To vrijedi i za niskoenergetske "uljne škriljavce" koji bi se mogli uporabiti u ciglarskoj industriji i industriji cementa, kao energetski i sirovinski dodatak.

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The History of the Exploration and Exploitation of Bituminous and Kerogenous Deposits in Croatia

B. Šebečić

Introduction

The history of exploration and exploitation of bituminous deposits, or natural asphalts and kerogenous deposits, respectively "bituminous" or "oil shales", sometimes confused with "stone" or "fossil coal", is connected in Croatia, according to old documents, to the early modern period. It is then that the first data are registered about the extraction of "piss asphaltus" "near Hvar, not far from from the Neretva" in Dalmatia (Matthioli, 1565), "earth wax" in Panonia, and "pegola" (It.: pitch) in Vinišće 1628, 1668, (Priuli, 1668; Barbaro, 1670).

In 18th and 19th centry Croatia new occurrences and deposits of pitch were found, and mines started (Paklina (the word itself means pitch), Škrip and other places) and in the middle of the 19th century work started here too on the processing of pitch (Vinišće, Škrip and other places). As well as this, part of the asphalt was exported to and processed in Venice. Asphalt production reached a peak in the second part of the 19th century and the beginning of the 20th century.

There can be various hypotheses about whether asphalt was extracted in Croatia in the medieval period, but there was certainly trade in asphalt, or pitch, as proved by documents from the 15th century. One such is the testament of the Zadar priest Zubina dated 1437 (Šurmin, 1898) on the back of wich there was written that Š. *Račić*, owned him 39 bolanč(coins)for bitumen ("pakal" in archaic Croatian). Another is document from 1381, of the Zadar notary Petrus de Sercane, who interrogated the captain of an Italian vessel, *Simon* dec. *Baghini* de *Bertanor* who had attempted to hide 12 barrels of "bituminous pitch" on board of his ship.

The exploration and mining of kerogenous rocks (oil shales), or their deposits, are certainly connectyed with the modern age, especially the end of the 18th century (1782), as far as the Brač deposits at Smirče near Mirca are concerned, as well as some small occurrences on the mainland, and the end of the 19th century, when the biggest Croatian deposit was discovered at Ruda near Sinj, as well as the Plješivica oil shales at Vrelo Koreničko, Baljevac, Zavalje and other places.

While the use of natural bitumens, and artificial bitumens (tars), was very important in the past for caulking wooden boats and for military purposes, the use of "oil shales" was in the past mostly important in health care, veterinary science and such like, finding its most important applications in the 19th and 20th centuries as an alternative energy source.

The aim of this research has been to provide an acquaintance with the history of a branch of mining which was in the past a significant part of the Croatian economy, especially in Dalmatia and Lika. A greater insight was desired into mining entrepreneurship, as was the collection of knowledge from renewed mining and geological exploration into the bituminous and kerogenous deposits of Croatia.

Natural bitumen and kerogen in the rocks

According to the recommendations of a study group of the World Petroleum Congress (Martinez et al., 1987) "natural bitumen is a component of petroleum that exists in a semi-hard state in natural deposits." This is a brown to black sticky, elastic matter, composed mainly of hydrocarbons (66%-89%), hydrogen (7-12%), sulphur (1-10%), nitrogen (<1%) and oxygen 1- 2%). Heteroelements usually account for <10%. It is otften contaminated with minerals, and if it infiltrates or impregnates rock, this becomes a bituminous rock.

A well-known synonym for bitumen (Lat.) is asphalt (Grk.); however, through later use the expression took on in Europe a homonymic significance, for it was used for rock infiltrated and/or impregnated by natural bitumen. In Croatian, some of the older expressions for bitumen are pakal (Vrančić, 1595) or pekl, which Skok (1972) links with "hell". Paklenica, which are in Croatia in some places geographical names of deposits of natural bitumen or asphalt. The word bitumen is also sometimes translated as "tar"(Bellosztenecz, 1760).

Bituminous shales are mixtures of organic and inorganic substances from which oil can be obtained, whence the name oil shales. Oil shales are characterized largely by the a very thin stratiform position of the sediments. They are more or less enriched by organic matter, later called kerogen, whence the name kerogenic rock (Schlatter, 1968, according to Yen et al., 1976). This term shows that through heating parafin wax or oil can be obtained from it. Kerogen is a fossilized organic substance insoluble in usual organic solvents while bitumen is soluble (Durand, 1980). Kerogen rocks can be interesting for petroleum geology explorations if they are mature, for they are the mother rocks for hydrocarbons. If in the rock in the organic substance there kerogen and bitumen (Fig. 1) they are bituminous kerogens, or kerogenous bitumens, according to which there is more of (Šebečić, 1983). The dominance of bitumen (90%) in the total organic matter of the rock links us to "pure" bitumen(ide)s.

It performed the first (Šebečić, 1978) complex division of carbonate rocks according to structural and textural characteristics of carbonate rocks, including their mineral and chemical composition, and then according to bitumen division and the pores of the rock in which the bitumen is located.

It is necessary to stress that in barren rocks with a very low organic matter content, that is, with low percentage parts of bitumen and/or kerogen, there can be relations of bitumen and kerogen in the total organic matter, as there are in genuine bituminous, bituminous-kerogenous and kerogenous rocks, wich has no practical meaning in application, unless the relations in the acumulation and migration of the contents mentioned are being studied.

Apart from divisions based on the relation of the bitumen and kerogen content in the total organic matter (Fig. 1), it is possible to

call, in accord with S c h m i t z' s division (1986) of a monotype organolite with asphalt, which he calls "raw asphalt," "asphaltide", and his corrected series would run as follows: pure asphalt-asphtaltide-asphaltenous rock, which with the synonym bitumen in our considerations would go" pure bitumen-bitumenide- bitumenous rock. In a similar way it is possible to make the series pure kerogen-kerogenide-kerogenous rock.

The basis for this division comes down to the mineral content contained <10%, 10%-50% and >50%. In complex divisions with bitumen and kerogen the term is determined according to the dominant type of organic matter.

Bituminous deposits and occurrences

According to well-known published data, one of the most ancient deposits of pitchy asphalt (pissasphaltus) is found "near Hvar not far from (the) Neretva" (M a t t h i o l i, 1565), which can refer to the Paklina of Vrgorac or the Slivno of the Neretva (Fig. 2) F o r t i s (1774) assumes that the Vrgorac mine worked before the "arms of Venice conquered this region". This seems to be logical too, because only a large deposit could have a long history of exploitation. About the asphalt deposit of Paklina archival documents exist (B o l d u, 1782) from which it can be seen that Croatian mining entrepreneurship in the region of Vrgorac was well organized as early as 1753 (Fig. 3), which was also written about by N o v a k (1962), S o l d o (1978), P e r i č i ć (1980) and others. According to Kišpatić (1901), who quotes F r i e s e (1858) it was written that the "asphalt stone in Vrgorac was being worked 150 years ago (i. e. in 1708), and many cases were held because of it."

In Dalmatia in 1850 production amounted approximately to 1, 000 Viennese cents (or 56 tons) of asphalt and over 2,240 tons of asphalt rock, which were transported to Venice to be made into asphalt mastic (F r i e s e, 1852).

It was *Baron Rothschild* who continued mining activity in Paklina in the middle of the 19th century; from him, the company was taken oven by *L. König and son* from Vienna. Mining was carried out along three mining districts called *Paulina, Maria* and *Alexand(e)ria*, from the names of König's children. In 1906, *Paulina König* took over the mine, and later the same year, the *Asphalt Gewerkschaft "Adria"* from Split, and in 1930, *Ruda d.d.* from Split. During the 1949-50 period exploration was renewed by Zagreb's *Naftaplin,* and in 1953 the mining company *"Paklina"* was formed, which was in 1961 integrated into the specialized building company *"Izolacija"* from Belgrade, a part of which it was for about 25 years.

Up till 1961 in Paklina mining went on underground, while afterwards exploitation went on open-cast mining. The approximate amounts of asphalt produced are shown in Table 1. It was established that after long interruptions brought about by world wars, the old pit works were partially filled up with natural bitumen, and the proportion of high quality raw material increased (Fig. 4). Leaking og bitumen from fissures and cave spaces is visible even today in open cast mining (Fig. 5). Bitumen also fills up cracks and other smaller hollows, crumbling fragments, and it is present more or less in all bituminous limestones and bituminous calcareous tectonic breccias.

In Paklina mining was done through a combination of shafts and/or inclines and galleries. Mining was done mainly at a depth of 50 m, where the deepest 4th working level (gallery) was located. The second incline was directed from the 2nd working level at 25 m towards a depth of 75-80 m (according to "Excerpts from the old mining plan M 1:1000, which was drawn up in June 12, 1945, in Split "which is located in the archives of the "Federal Geological Institute" in Belgrade) and thus allowed for the achievement of the greatest depth in the subterranean mining work in Vrgorac. The deepest vertical shaft is found in the Paulina mining districit, 55 m deep, while the depth of the air shaft at the Alexandria mine field is about 40 m.

According to Š i n k o v e c (1957) in the region of the previous asphalt mine region "Aleksandar" (earlier called Aleksander or Aleksandrija) there are reserves of B category asphalt breccia of 45260 tons, and 30000 tons of C1 category, inside and between the air and the cross shaft. Šinkovec assumes that in the region of the one time "Aleksandar" mining district about 50000 tons of asphalt breccia was taken out. He concludes that in the region of the Paulina and Marija mine fields there are reserves of asphalt breccia, although the fields were not available for him to do research into. The proven reserves of bituminous, or asphalt stone have been established at 86300 tons, including 16400 tons of A, category, 25100, tons of B category and 44800 of C category, with a 10%-18% bitumen content but with an estimated 340000 tons of 7.2% bitumen, with the proviso that 60% of the reserves have 12% bitumen content (P a t r l j, 1975). The question of the evaluation of reserves is linked with difficulties about the direction of future exploration, for the results before the exploratory drills made are very modest.

At Vrgorac a plant for raw material processing existed, and consisted of a crusher, a mill and a plant for the preparation of mastic and insulated sheets. In the past, many bridges, terraces, insulated warehoues, reservoirs and other things in Europe were covered with Dalmatian asphalt. In 1886, several crystallization salt basins in Ston were covered with Vrgorac asphalt; St Mundo was still almost undamaged in the fifties of the 20th century. The greatest part of Sarajevo was also asphalted with this material (A n o n., 1932)

In Vinišće, natural asphalt was being exploited in 1668 (Fig. 6) and in 1628 (B a r b a r o, 1670, S o l d o, 1978) and is assumed to have been earlier too (Š e b e č i ć, 1984), for natural bitumen was mostly used in the middle ages and partially in the modern period for the bitumenization of wooden ships. Only unreliable hypotheses can be made about whether any of our most ancient deposits of asphalt were known in the period of the Croatian rulers, of Prince *Domagoj* (9th century) and King *Zvonimir* (11th century when there was a powerful navy. According to an oral communication from my late colleague *Hanich*, Vinišće might have been a harbour for ship repairs, for reviewing photograms of the sea in the Vinišće bay he noticed the remains of pillars for tying up ships, and the deposits in Vinišće are close to the sea. Since the occurrences of natural bitumen on Brač and Čiovo (F o r t i s, 1774) are not significant, the deposits in Vinišće might well have had an appropriate importance in the distant past, especially since artifical pitch (tar) is not mentioned in the statutes of Brač and Trogir, as it is in the middle ages and later mentioned in the statutes of the islands of Korčula and Hvar and elsewhere, where pitch was made from fir and pine, for there, in the past, no deposits of natural asphalt were recorded, and the needs for artifical bitumen for the ship-yards of Korčula, Hvar and Venice were quite considerable (P e d e r i n, 1990)

The owners of the Vinišće deposits were the see of Trogir, according to which the deposit on the hill above Vinišće was called Vinisce-Episcopal (Biskupija) (Š e b e č i ć, 1984) and the Trogir Abbey of the Benedictines (Vinišće-Opatija, S e b e č i ć, 1984). As late as 1670, at the appeal of the Trogir see's "Council of Ten" it was forbidden for mining entrepreneurs to do anything on the hill above Vinišće, because they were usurping the lands of the Diocese. Similar attempts where made approximately 175 years later, after the renewal of mining activities in Vinšće Abbey (Opatija) when the heritor of the Abbey, the Split Seminary sought protection from the Trogir Curt, whic banned the removal of asphalt from Vinišće to Venice, while the entrepreneur Baron *Rothschild* did not buy plots of land where the deposits were found. Alongside the Vinišće-Opatija deposits, the German engineer Hermann, Rothschild's factor, set up several mills (S l a d e-Š i l o v i ć, 1939) for crushing asphalt limestone, and a vat or stove for heating and melting the bitumen, which was afterwards strained into barrels, or, from the black slurry, mastic cake was made, and was as a semi-finished product or only as a raw material, transported in sailing vessels from 1840 on, and, it can be assumed, until the end of the 19th century to Venice and elswhwere.

In Vinišće, according to B a u č i ć (1943) there was the first Croatian asphalt factory, which stopped operations on the eve of the First World War. Vinišće asphalt, aparat from being exported together with that from Vrgorac and Škrip (M a r s c h a l l, 1856) to Venice, and elsewhere in Italy, Austria, Prussia and elsewhere (T a m b u r i n i, 1852) was used also in Dalmatia for the asphalting of storehouses, terraces, underground rooms and the salt pans in Ston. A contract has been preserved between *E. Hartung,* an

entrepreneur from Vinišće, and The Financial Office of Dubrovnik, made up on July 5, 1874 for asphalting the salt pan St. Frano/Francesco/ or St. Francis, whith the area 845 square "klafters" and 4-5 cm thickness. In a later contract of May 25,1876 Hartung undertook to asphalt the crystallization pan "Mondo" of similar size i.e. 870 square "klafters" (3,130 m2), which was paid 5,220.91 florins (grand-total) after taking over asphalted pan (S l a d e-Š i l o v i ć archives, Trogir).

After World War II, it was estimated that at Biskupija there were from 10,000 tons of asphalt reserves (S i l a, Š i n k o v e c, 1955) to 25,000 tons (G e m b a č e v et al, 1956) and trough exploratory drillings it was calculated that there where proven reserves of 100,206 t (Š e b e č i ć and T r u t i n, 1985), including 97,461 t of B category reserves, and 2,745 t of C1 category. It was estimated that there were potential reserves (C2+D1) in the northern zone, as it is called, where there has never been any drilling, so that all proven and non-proven reserves are estimated at about 175,000 tons, with a 69% degree of exploration. It has been established that the biggest bituminous body has a very complex structure. This is in fact a massive (Fig. 7) to stratified in thick beds body that is 0.10m - 26.20m thick. The average free toluene-bitumen content of the largest bituminous body comes to 3.05% (79 analyses), and glowing loss to 550°C, by which the kerogen and bound bitumen content were evaluated, was 0.58% (76 analyses). The average weighted free bitumen content for the drilled region was 2.29% (130 analyses), and glowing loss was 0.65% (130 analyses). Altogether for Vinišće Biskupija the average bitumen content for 181 analyses was 2.00%, and glowing loss to 550°C was 0.76%. Altogether from the 213 analyses so far made average bitumen content has come to 2.24%.

Bitumen is found in various genetic pores of senonian biogenic limestones mainly in biomicrudites and bio(pseudo)sparrudites Gg- Pp-Ww-Pp-Gg of limestone sequence, which are characterized by better qualities as collectors as compared with underlying and overlying biomicrite limestone. Apart from the exploratory drilling, in the course of which 34 exploratory drills were made between depths of 20 m and 66.8 m, with an average depth of 32.23 m, mining and geological research was carried out by mining trenchs, adit and deepening the old shafts. Of the old mining works two "min(j)ere" stand out, which are linked by a tunnel and one exploratory shaft. From this we can conclude that only a small amount of the reserves has been extracted from Biskupija.

The bituminous deposits of Vinišće-Opatija (Fig. 8) have been deep mined, in three levels, with the deepest level at 15 m, where sea level was reached. Because of the proximity of the sea and residential housing it is not suggested that exploration in this region should be renewed. Bituminous limestones are biomicrites in type wackestone (w) and contain 2.04% bitumen (4 samples).

Of the other Trogir bitumen deposits apart from Vinišće the most important are the bituminous Upper Cretaceous limestones of Balovi in Primorski Dolac and the bituminous Upper Cretaceous dolomites of Ninčevića Lokva in Radošić. The first deposit was mentioned in the past under the name of Suhi dol (S c h u b e r t, 1909), and earlier still, in 1804, a Suhi Dolac, which is the old name for Primorski Dolac. This is a shallow, open pit on a hill slope (Fig. 9) known among people as Paklinka, while another, smaller deposit was later discovered in Radošić (S c h u b e r t, 1909), with there being a shallower surface mine in the meadow. All the others are smaller bituminous occurrences., including that on Čiovo, which Fortis described in great detail in his travelogue of 1774 (Fig. 10).

The first response to Fortis's description of a "mine of pitcy asphalt" on the western cape of Čiovo was made by an unknown informant of Maria Theresa (S o l d o, 1978), who wrote about this bituminous occurrence (in approximately 1776) that it was of excellent quality, but that only a few pounds could be collected, just two to three kilos (N o v a k, 1962). P e d e r i n (1991) presumes that this secret report was written by some person from the circle of *Wilhelm Bolts,* a German born in London, who is responsible for the founding of the *"Triester-Ostindische Handels kompanie"* 1776 in Trieste. The unknown report blamed Fortis for suggesting to the Venetian authorities, on the basis of inaccurate information, that they should go in for exploiting the deposits, which nevertheless they did not do. Then, the informant writes that there was a bit more pitch at another place, near Škrip, on Brač, in a valley before Vrgorac (the occurrence of Kotezi) and not far from Sinj (Đipalovo vrilo) and south-west of Sinj.

In the Neretvan region at the foot of the Raba Mountain, that is in Slivno, Fortis mentions another mine of asphalt, with the proviso that he had not visited it. The asphalt "mine" of St Ivan (as he called it, without evidence) in "Pučišće" in Brač was also not found by Fortis, although Dr *Bajamonti* was supposed to have shown him a sample from the locality. Fortis stated that the fossils in this asphalt stone were different than those he had seen in other asphalt deposits in Dalmatia (F o r m a l e o n i, 1786).

In the northern part of the island of Brač, not far from the town of Škrip, lies an abandoned asphalt mine (Fig. 11), of bituminous dolomite, where there was mining between 1750 and 1874. The biggest part of the mine is made up of several large cavern halls which were partly filled with accumulations of bitumen (Fig. 12) while in the incline and in the lateral galleries there is in places just a little asphalt, in narrow layers or spatterings. Therefore it is understandable that mining was abandoned. Nor were positive results given by later renewed mining activities with two adits in the eastern part of the deposits or by shallow exploratory drilling, and so mining was abandoned altogether in this reason. As for more ancient mining works, a few trenchs are recorded at the eastern deposit.

Bitumen was extracted from the Škrip asphalt in two round stoves mainly. The stoves were destroyed and one was filled in. The western part of the deposit was richer in bitumen (2.63%-9.40%) than the eastern (0.09%-3.19%). One the basis of 26 bitumen analyses it was calculated in 1968 that the average bitumen content was 3.57%, and out of 50 analyses, among which there were analyses of samples that were richer in bitumen, it was calculated that there was a 5.94% bitumen content in the Škrip asphlats (K a n a j e t et al., 1995). Škrip bituminous dolomites and traces of bitumen in the rudistic limestones, or "Brač marbles", belong, according to J e r i n i ć et al., (1994) belogn to a part of the Pučišće formation. The kerogenous stromatolitic limestones of Mirca and Brizi on Brač belong to part of the Sumartin formation (G u š i ć and J e l a s k a, 1990).

As well as in the *Škrip* mine field, bituminous dolomite was extracted considerably later in the *Brač* mine field in Pod Badanj. Bituminous limestones are found not far from Pučišće and in St Martin (Sumartin), in the *Dalmacija* mine field, partly at Splitska and Mirca. Kerogenous limestones, or "fossil coal" were extracted in the *Wilhelm* mine field south of Mirca, *Gustav* and *Herman,* in north west Brač, and in *Kolači,* south west of Nerežišće, and in field called *Austrija*, south of Dračevica, in the south west of Brač. There are other kerogenous limestones at Bole, Zečevo, Postira and Sutivan (J e l a s k a et al., 1983).

All mining concessions (T o m a š i ć 1949) obtained under Austro-Hungary were in orperation in the Kingdom of Yugoslavia, which is an indication of the one-time interest in the exploitation and application of both bituminous and kerogenous rocks. It is necessary to stress that the deposits mentioned were never subjected to detailed geological research, irrespective ot the level of their mining research, and so it difficult to evaluate their geological reserves.

At the beginning of the 19th century there was in Škrip a production of natural asphalt with 9-10% bitumen, which was exported together with the asphalts from Vrgorac and Vinišće in wind powered merchant ships to Venice (M a r s c h a l l, 1856), where it was processed, either in the form of a semi-finished product or in that of a raw material. Product obtained via the processing of natural asphalt from Dalmatia were shown at the Paris Exhibition of 1855, where there were 30 exhibitors from France, Austria, Bavaria, Spain, Portugal, Canada and Mexico.

Rights to extract asphalts from Brač and Vinišće were gained in the second half of the 19th century by *Heinrich (Enrico) Hartung,* an entrepreneur from Trogir, of German origin. This is given in the mining exploration license based on the Austrian mining law of 1854. This relates to the area covered by the Split and Sinj port authorities. Hartung obtained it in 1873 (Fig. 13), and extended it in 1874. His 1879 certificare for free asphalt exploration in Vinišće

is also preserved. According to N i k o l i ć (1900) the Brač deposits in St. Martin, Mirca, Škrip, Splitska and Nerežišće were explored by the mining engineers of the *Steinkohlen Gewerkschaft* in 1840. Of all the deposits, most was promised by that in Škrip. However, in spite of a high production of 6.735 tons in four years, the Škrip mine got into difficulties and the bank let the mine out to private enterprises. In 1873 the mine was leased by the French *L'Asphalteine, Societe Anonyme des Asphaltes et des Bitumes de L'Adriatique*, of Paris, from *H. Hartung* of Trogir. From documents of the Royal and Imperial notary *Dr A. Hochkofler* From Trieste dated January 15, 1874, it can be seen that Hartung promised to sell Asphalteine concessions for asphalt exploration. Since Hartung probably did not sign a contract, for he was given a reminder, it can be assumed that Asphalteine, seeing the complexity of the mining and geological situation in the Škrip mine gave up the right to priority exploration of the asphalt ore, and asked Hartung to keep 400 tons of asphalt already extracted in storage until a purchaser should be found (Fig. 14). As far as the asphalt deposits on Brač are concerned, S ö h l e (1900) most of all describes Škrip, the thickness of whose dolomite "sand", rich in asphalt, was estimated at about 20 m.

According to P e r i č i ć (1980), G. *Billio*, probably Croatian Bilić originally, a geological explorer and mine entrepreneur discovered coal near Skradin, at Promina Mt. (Siverić, Dubravice and Velušić) and fossil coal on Brač (Smirče), where he also discovered asphalt. According to *Diedo* (S o l d o, 1978), *Billio* obtained together with *D. Stressi* in 1782 the right to extract fossil coal throughout Dalmatia. Thus Billio began to mine fossil coal, that is kerogenous stromatolitic limestone on the terrain of Smirče (near Mirca, author) two kilometers south east of Sutivan, from which it was taken in sailing ships to the Rijeka sugar refinery. In a letter to his factor *P. Bergalić, Billio* said that at the beginning of 1791 there were about 12 waggons, or approximately 114 tons of "coal" stored in Sutivan.

In 1784 and 1785, *M. Šimunović and N. Šimunović,* as well as *I. Srempić and M. Beroš* obtained from the magistrates a license to extract pitch from three "holes" in Martinica or Smirče. In 1781, *A. Lovrić* from Sinj, together with *V. Celio-Cega* (S o l d o, 1978) obtained a license to mine black asphalt on the St Ciprijan Cape by Trogir, on payment of tithes, but it is not known whether extraction of asphalt was actually done here. In 1782 the Economic Society of Split was informed by letter about the occurrence of patches of tar on the mountain of Hum not far from the Benedictine monastery and church in Komiža, on Vis by the Split physician *Barbieri,* who said that the people called the place Paklenica, that tar (i.e. pitch) was dug up in this place and used for caulking the fishermen's boats (Ž g a l j i ć, 1984). In 1786, the *Moscatti* family gained the right to extract asphalt at Siveric; however, because of great losses, they gave up further extraction when the license expired (P e r i č i ć, 1980).

After the downfall of the Venetian Republic, Istria and Dalmatia became parts of the Austrian Monarchy. The mining wealth in this region then known was registred in the Hofkammer (Court Chamber of Commerce). A tabular report about these explorations (Fig. 15) was drawn in in 1804 by P a n t z and G a r a p i c s; it was published, almost 190 years later, by E r c e g (1992). In total, they described 26 localities, of which 7 had earth pitch, that is: Barban in Istria, Suhi Dolac, Vrgorac, Slivno on the Neretva, Čiovo and Brač (Mirca and Nerežišće). Earth pitch, or bitumen, lies in limestones and sometimes in lime marls. Pantz and Garapics determined that most of the localities had no value; the Slivno deposit was determined to have no useful natural product, while the Vrgorac deposit was assumed to have little expectation of being economically exploited, which was later contradicted. As for the deposits on Brač, they said that they had been explored during the the period of Venetian rule.

Among the Mosor bituminous deposits the first to be mentioned is the deposit in Dolac (H a u e r, 1850), or, in more detail, in Krivi Dolac (S c h l e h a n, 1851) where large mining works were carried out, the expenses of which for the period 1849-1851 were included in the current accounts (Fig. 16).

From the current account made up between *Direction der adriatischen Asphalt Werke zu Venedig* and *Andrija Gross* (1852) from Split it can be seen that the total earnings amounted to 15,748.52 fl., while expenses were 17,519.2 fl. In the expenses mention is made of those incurred by the Mining. Authority on Brač (1364.19 fl.) and in Vinišće (530 fl.) and in the mining works in Vrgorac (300 fl.); hower, the major costs were incurred by the "Management of the Venetian Asphalt Processing Co.," during part of 1849, in 1850 and part of 1851 in the Mosor asphalt region, including Krivi Dolac (~4,967 fl.)

Afterwards R i t t e r et al (1855) wrote of pits north east of Split, probably in the Dolac region, which were called *Alleanza, Fedelta, Fiducia* and *Madonna delle Grazie.* Later, K e r n e r (1916) described the asphalt deposits and occurrences in Donji Dolac: Okruglice, Putišća Stan, later called Staje, Na Privaj, Gornja Rošca and Akrap, and later (1919) also Župa, Kozica, Drežnica, Štikovo, Radošić etc.

The Fedelta mining field in Krivi Dolac was assigned in 1847 to *Cerineo* and *Gross,* and later in 1850, very likely sold, to Rougieri. From 1930 on it was owned by *Ruda d.d.* Split. The neighbouring mine fields *Paul* and *Virginia* in Okruglice were from 1904 owned by the Hamburg *Bergwerkgesellschaft,* and from 1930 on were leased out to *Engineer Grochowalski,* the one time manager of the Vrgorac mine. In Gornja Rosca (Donji Dolac) and Akrap (Bisko), *Vidović* and *Sisgoreo* of Split had, according to local oral information, an exploration concession. In Dolac Donji, i.e. Krivi Dolac, the mining exploration was financed bu the Vice- Regal (Banovina) Goverment in Zagreb too (Fig. 17).

In Gornja Rošca exploratory works were undertaken by trenching, and a little exploitation by deep mining. Through test drills it was established that the bitumen lay in the Upper Cretaceous and in the Eocene limestones and in tectonic breccias. Further, it was established that there was a deep link between nearby surface occurrences. The thickness of the bituminous bodies was on average 17.7 m. The bitumen content was on the whole grteater in the outcrops than in the drilled sedimentary layers, the higher quality raw material was only 1.5-6 m thick, and only exceptionally 16 m. For all sediments drilled the average bitumen content amounted to 0.76% (from 70 analyses), while it was for one drilling higher, that is, 1.62% for 27 analyses (Š e b e č i ć, 1981). The average estimated insoluble organic matter content was 1.88% for 70 analyses from 6 drillings (Š e b e č i ć, 1977). According to the relation of free bitumen in the total organic matter in Upper Cretaceous limestones weakly kerogenous-bituminous limestones are more common, while in palaeogenic limestones there are weakly bituminous-kerogenous limestones and weakly kerogenous limestones. It has been calculated that only 10% of the reserves contain good quality raw material (Š e b e č i ć, 1977).

In the context of a review of Yugoslav, or Dalmatian natural asphalts, A b r a h a m (1960) distinguished the Vrgorac, Brač and Morovice asphalts with old analytical data, while he erroneously put into Montenegran (it was perhaps suggested that he should do so) the deposits of asphalt in Dubrovnik, Vinišće, Čiovo, and Suhi Dol ac (North Trogir) asphalts, as well as asphalts betqween Drniš and Knin. Thus for example he writes that the Morovice weakly dolomitized limestones from the region of Šibenik contained 10-15% asphalt, while the Vinišće crystalline limestones have 9.2%, and the Dubrovnik (probably Gnjili Rat) limestones had 13.9% asphalt. The term for the asphalt locality Morović or Morovice probably derived from the name of the village Mokro on the border between the Sibenik and Trogir disticts (S t o š i ć, 1941), and comes within the Danilo-Biranj parish.

That the asphalt deposit in Gnjili Rat on the Pelješac peninsula was explored, if not exploited, in the 19th century is documented by the bitumen analysis of "probably" 25% (T r i n k e r, 1868). According to chemical analyses (J o h n and E i c h l e i t e r, 1901) the asphalt limestones of "Poljica" (D. Dolac) contained 32.94% bitumen, those of Vrgorac 31.04%. Later, a bitumen content for the Vrgorac asphalt of 16.32 was arrived at (E i c h l e i t e r and H a c k, 1920).

In Kozica Upper Cretaceous bituminous dolomites were explored before the First World War. There were two inclines of 25 m in length them. The bitumen content varies between 0.90%

and 11.20% ($\bar{x}$=3.87%, N=20), and the thickness of the bituminous zone was 1.5-3 m.

S c h u b e r t (1909) says that the most important asphalt deposits in Croatia are in Vrgorac, which was well known in the 18th century, and after that, Kozica, Dolac, Radošić and Suhi Dol, Prapatnica and others, and on Brač there were Mirca, Pičišća, St. Martin and Škrip. These are all Upper Cretaceous deposits and occurrences. Of Jurassic deposits he mentions Štikovo, Kijevo and others, and those in Pelješac and Čiovo from the Eocene period.

At the end, there is still the unsolved problem of the origin of the spherical, secondary clusters of pitch (bitumen) washed up on the Pakleni Islands. For the moment it is ungroundedly common to link the occurrences of pitch with the name of the Pakleni Islands (Ž g a l j i ć, 1994), for Croatian fishermen know nothing of mining for pitch on the Pakleni Islands. It is a fact that the fishermen used this spherical, apple-sized flotsam, sometimes even biger, and that they were found scattered over the bay beaches, much more over the northern than the southern sides of the islands. According to an oral communication from *N. Gazzari,* shipbuilding engineer from Hvar, the "ball-shaped" flotsam was brought by the currents, with the maestral wind from the north-west (Čiovo and/or Vinišće-Opatija) or from the south or south west (the Neretva valley, or closer, from the eastern part of Hvar). Apart from this the possibility should not be excluded that there is some submarine occurrence of bitumen or oil that should be investigated.

East of Novska, especially between the Paklenica stream (Fig. 18) and Voćarac, several deposits of bituminous weakly bonded sandstones have been registered (Š e b e č i ć and B u l i ć, 1983). They are about mm to m thick (maximum drilled 1.35 m). On the basis of geological cross sections trenching, cutting and prospecting-exploring drilling it has been concluded that the bituminous sediments are limited in volume, because they alternate with barren sediments. In drillings, thus, the ratio of barren rock to ore varies from 4:1 to 15:1. The bitumen content in the neogenic sediments of *Banatica beds of* Paklenica varies from 0.10 to 10.12% ($\bar{x}$=3.76%, N=37). The geological reserves between the three drillings are estimated at 50,000 tons, and it is predicted that they might even be greater (Oreški and Đurđanović, 1983). Because of the thinness of the layers and the steepness of the bituminous sediments, and their unfavourable relation to the barren sediments, not to mention the destruction of forest that would be required, it is not recommended that there should be further research in this region.

According to A n o n (1920), north east of Bačindol (Fig. 18) towards Cernik a fairly light oil pitch was found in several mine shafts. This encouraged a group of business people, *Count Erdody, Baron Gruttschreiber* and *traders from Sisak* to build, in 1858, a factory of mineral oils, to obtain train-oil and lubricants for trains and coaches.

In Paklenica, Mikleuška, where a train oil factory was also built in 1860, and at Voloder on the slops of the Moslavacka hills, pitch was found in tertiary sediments. In a larger deposit in Paklenica several Viennese cents a day of pitch and oil mixed with water were extracted from a shaft 45-60 m in depth. Later, 1905 the *Vesta Co.*, showed by drilling the presence of pitch at a depth of 70 m, and earth gas at even greater depths. At Voloder, 4 km west of Mikleuška, the presence of bituminous rocks 4-6 m thick was demonstrated in a drilled sedimentary layer at a depth of four metres, from which a dark green oil oozed.

At Veliki Poganac (Fig. 18), drilling revealed nest-like gatherings of earth wax in shale, which would melt at 70°C. An occurrence of oil was discovered in this region after the earthquake of 1882; however, the exploratory drillings performed subsequenly did not give positive results.

Z a p h a r o v i c h (1859) wrote in his Mineral Lexicon that there was pitch in Peklenica (Fig. 18) in Međimurje, in tertiary sand on the bank of a brook, and in a shaft 3.9 m deep. This was repeated by R a u k a r (1932), who said that in 1836 a dark brown earth oil was obtained for train oil.

Kerogenous deposits and occurences

Oil, or kerogenous sediments are found in various localities in Croatia in Dalmatia, Lika and Istria, and elsewhere (Fig. 18). Once upon a time crude oil was obtained from them, in Ruda, near Sinj, and Baljevac, near Bihać; it can be assumed that it was too in Brušani near Gospić. The oil was used for various purposes: medical, for power, and so on. According to knowledge to date, it can be concluded that the most high quality raw material was exploied at Ruda near Sinj and at Vrelo Koreničko and Baljevac. By research into the majority of the occurrences and deposits it has been stated that the quality of the raw material in most localities can be used for low-energy requirements.

Subsequent exploration of the kerogenous deposits showed that a small part of the material was of good quality, because barren and kerogenous parts alternated in them, which considerably reduced the proven reserves of the deposits. Current exploration has not shown that there are any thicker-layered and stronger kerogenous sediments.

Of the Croatian deposits of oil shales the most important is found in Sinj - Ruda (Fig. 19), because it is rich in oil (30- 40%), and its reserves are estimated at several milion tons (L u k o v i ć, 1936). The other deposit is Baljevac, with thin layers of up to 0.5 m, which were exploited for a short time, between 1901-1905. chemical and pharmaceutical company *"G. Hell"* from Troppan (Mining captaincy Zagreb, 1893-1901), From them, "ichthyol" was produced. As for oil shale occurrences in Croatia, E r c e g o v a c (1990). concluded that they had been only slightly explored, because there were no data about organic-petrographic and geochemical characteristics. This refers above all to the occurrences of Trlji and Šaini in Istria, to Poštak in Lika, and to Svilaja and Ruda in Dalmatia. He considered that the occurrences of Poštak and Ruda should be studied in detail, because the kerogen in them is of the sapropelic type.

It is assumed that oil shales were begun to be explored in Lika in the 19th century, for they were being pocessed in Baljevac 1901-1905. According to a translation of an anonymous German author we can conclude that the exploitation was divided into 5 concesions: *Baljevac*, owned by *J. Patta, (R e i t t e r,* 1926) *Zavalje, Vrelo, Lapac* and *Korenica,* with a total area of 51400000 m^2. Reserves of 20000000 tons are quoted for Lika.

In Baljevac, exploitation of the Lower Cretaceous oil shales which was prior to the World War II performed by the *Lika Mining Association* and the *"Gyrodal"*, Zagreb. There were four minor works (Fig. 20) at which mining was done by strip-mining, and by a combination of inclines and lateral galleries of some metres in length. The subsequent extraction of ichthyol was done in 8 retorts at a temperature of 520°C for 3 hours from pieces of crushed oil shale the size of walnuts. Daily production of oil from the Baljevac deposits were 1.60 t - 1.92 t, or maximum of 700 t a year.

From the Zavalje, or Suhi Dol deposit, which was exploited by a combination of cuttings, adits and galleries, about 0.2 t to 0.8 ton a day was obtained, or about 180 tons of oil a year (1947), and from the Međudražje or Bijela Greda deposits 0.4 t to 0.5 t daily. There are no figures for production of the Korenica deposits, where exploratory works were done with two tunnels 12 m and 6 m in length.

Shales were processed in the oil factory in Baljevac, which after World War II belonged to Bosnia-Herzegovina. The old distillation plant was destroyed in the war, but after the war it was renewed and for a short time worked at full capacity. The exploitation of oil shale was done with strip mining, and the mining was done partly by Croatia, and partly by Bosnia-Herzegovina inside the ichthyological dolomite zone.

In Vrelo Koreničko there are two deposits of Upper Jurassic kerogenous rocks: Zubovića Draga and Mrsinj Grad (Milanovića Draga) for which mining exploration was done under Austro-Hungary at the turn of the century, and which were exploited for a short time after World War II up to and including 1949. Ten years ago, geological, organic-geochemical investigations were renewed again, of both the Vrelo Koreničko and the Zavalje deposits of kerogenous rocks (Š a b a n and Š e b e č i ć, 1984, Š e b e č i ć, et al, 1990 and others), while below Mrsinj Grad exploratory prospecting drilling was carried out (S t o i s a v l j e v i ć et al 1988). It was found that the organic matter content changed both vertically and laterally (0.06% - 6.57%, exceptionally 68.42% ("kerogeonoides") which was rather strikingly visible from the

lower thermal values of the drilled kerogenous rocks of Mrsinj Grad (0 to 17,401 kJ/kg, x̄=1986, 10 kJ/kg; 52 samples from 7 drills, Š e b e č i ć et al, 1989).

Since energy is an important input in the production o brick (40%)in 1989 we attempted to determine the technical and economical aspects of the first industrial application of oil shales in Croatia as follows: 5% or 10% mass of oil shale i.e. mass of kerogeonous dolomite and kerogenous chert from the Zubović Draga deposit by Vrelo Koreničko was mixed into the raw material for brick production at Zagreb Brickworks.-The preliminary industrial testing with (3%-5%) oil-shale with a lower thermal value of 1421 kJ/kg, and industial testing with 10% oil shale with a lower thermal value of 1250 kJ/kg produced a hollow brick of dimensions of 250x190x140 mm grade 15 and grade 10. An economic analysis based on prices in January 1988 showed that it was profitiable to use oil shale as an addition if it had a lower thermal value of 3767 kJ/kg (Š e b e č i ć et al. 1989) which could be provided only by a smaller selected part of the oil shale, and so these mining and geological explorations were abandoned. Only a shorter transportation route to closer brickworks, in Perušić for example, could justify the use of oil shales of lower energy values.

In Postak in Lika kerogen sediments are registred in the south, west and north wing of the brachysyncline which has been photo-geological countoured by J a k i ć (1984). The kerogenous sediments extend for 17 km in length, and their thickness is 30(-50) m. These are Upper Jurassic kerogenous limestones - biomicrites, and more rarely fossiliferous micrites and cherts alternating, and dolomites. Only the regions of Dimići and Vagan are somewhat richer in organic matter. For example, the C org content in Dimići samples varies from 1.93% to 7.12% (x̄=4.38% from 19 samples).

According to *Tancig* reserves amount to 2000000 tons (Č u b r a n i ć-A j d u k o v i ć, 1981), in the region of Rastićevo that is, or Mijina Glava, where in 1949 exploratory works were carried out for the purpose of starting up open cast mining. P e t u n n i k o f f (1938) had already shown that there were richer regions with more organic matter, in Lisine and Viline Plećine (Vagan); he calculated excessive reserves of bituminous shales for the whole deposit (900 million tons). Poštak is a large deposit, but largely of low quality raw material.

A kerogenous occurrence in Vagan, in the village of G. Tiškovac in Lika was known before World War II (P e t u n n i k o f f, 1938). It is composed of Upper Jurassic Lemeš sediments, largely slumped and laminated dolomites with quartz nodules. A component part is made up of the kerogenous lenses the length of which is estimated at 10 m - 12 m. In The lenses there are kerogenous siltstone with radiolarians. There is more free bitumen in the dolomite (5.24%) than in the siltstone (0.67%). The total organic matter in the analysed dolomite amounts to 49.38%.

I. Ulrich, surveyor and mining entrepreneur from Sv. Juraj (St. Georg) in Styria had registered explorations and mining in Lika, and obtained ditching licenses in Gospić (Brušani, Medak, Smiljani), Perušić (Kosinj), Gračac, Donji Lapac and Srb. After a certain time *Orešković* from "Royal Mining Captaincy" from Zagreb sent on Nov. 12, 1882 a question to the "Royal District Court" in Zagreb asking it to find out if the given communes Ulrich had actually done mining. On the same date he also sent an enquiry to "Royal Tax office" in Gospić, Gračac and Otočac and to see whether Ulrich had paid the ditching taxes, especially the arrears for the 3rd quarter of 1882. From the one answer preserved, from Gračac, it could be concluded that Ulrich did not doing any mining there.

By investigation into the fossil fauna of Dalmatia, M a r g e t i ć (1952) showed that there are several working levels "of sedimented bituminous (i.e. kerogenous) rocks" of Upper Jurassic, Upper Cretaceous, and Tertiary provenance. Thus he called into question the older opinion of the Viennese geologists that the origin of asphalt should be sought in the Upper Jurassic limestone plates. The environment for the creation of the mesozoic (kerogenous) sediments according to M a r g e t i ć (1952) was marine, of the older tertiary sediments brackish, and of the younger tertiary lagoonal. Š a h n a z a r o v (1941) had even earlier noticed differences in the genesis of the bituminous rocks of Brač, and as well as natural asphalt, saying that there are pyrobituminous rocks, as M a r g e t i ć (1952) and later K r a n j e c et al. (1964) were to call them subsequently, sedimentary bituminous rocks lying in two working levels with natural asphalt coming between them.

In connection with the sedimetary bituminous rocks of Brač, K r a n j e c et al. (1964) conclude that because of their greater plasticity within the thickly layered limestones they are secondarily disturbed, that is, micro folded and micro faulted and crushed. Mainly they are characterized by a fine-layered, later called laminated, structure, in which there are alternate layers of carbonate and bituminous rocks. In the bitumen it has been microscopically determined that there is an alternation of lighter and darker leaf formations and "irregular speckled agglomerations and smaller dark dots of unclear origin (i.e. kerogen)". A migration of lighter coloured bitumen into the veins and reticular accummulations was noticed, and also into the rhombohedral pores in the dolomites.

According to M a r g e t i ć (1952) there was intensive mining on Brač (Brizi and Dujićevo), Drežnica (Mirilović Polje), Bitelić and Vrdovo and Unište. In palaeogenic kerogenous Upper Cosina limestones, bituminous marls, of Plana a tunnel of 120 m in length was made, and a number of shallow shafts. In Antunovići two shafts of 2 - 7 m in depth were made.

According to Schlechan (F o e t t e r l e, 1851) in the roof of the main coal floor layer at Siverić in the Barbara shaft there are bituminous marly shales, although no description was given. It was establised that the stinking kerogenous limestone or shale from Kremena in the vicinity of the Neretva contains 52.7% ash. By distillation, 23-26% tar oil was obtained from it (A n o n y m o u s, 1873).

In tertiary sediments oil shales were discovered in Rude, and here, according to T u ć a n (1925), a mine was established in 1898. The gasworks in Split used the oil shale from Rude to make gas for lighting and for tar. After World War II, for a short time mininig and geological explorations were resumed, and the reserves were partially calculated to be 2.3 million tons (Š e f, 1956). An estimate of part of the reserves for the southern part of the syncline was based on the results of 4 drillings over a surface of 1,500 x 1,500 m, with a thickness of ore of 2.4 m; thus reserves of 1,800,000 m^3 were calculated. Analysis of 4 samples of the nucleus by the Fischer method determined that there was 6.7% to 18.7% oil (x̄=12.5%). T a k š i ć (1948) estimated the total "coal" reserves of Ruda near Sinj, that is of oil shales, of 360,000 t; however he considered that at least 25% of the reserves had already been removed, and so only 270,000 t remained. The least favourable variant gives only 100,000 t of raw material, and if 25% has been extracted, this leaves only 75,000 t of material. He quotes the opinion of miner *A. Polaska* who thinks that the coal layer in the mine was about 1 m thick,and that there were 4 working levels which were linked by a dip heading. According to *Petrunić* (1951) the "bituminous shales" of Ruda constituted a "first class facility with good amortization". The use of the shales in the cement industry was being thought of here.

Of the older mine workings, nothimg has remained that is accessible, for the works were ruined or filled in, just as the entrance to the last tunnel was filled in right next to the village lane (Fig. 19), where I myself measured a 5 m thick zone enriched with organic matter in which dark and light coloured laminae alternated. The darker laminae were rich in kerogen, while the lighter laminae were poorer, or almost without kerogen.The organic matter was immature, and so these rocks must be excluded from petroleum-bearing rocks (Š e b e č i ć and E r c e g o v a c, 1983). In part of the kerogen zone in Rude a great fish farm has now been built which in part reduces the opportunities for exploitation. Because of the steepness, the layers and the undefined depth of the slope, it was questionable how economic it might be to resume extraction from these kerogenous deposit.

Of the kerogenous deposits on Dinara. I would lay emphasis on those on Golo Brdo near Vrdovo. These were explored in the fifties of this century (M a r g e t i ć, 1952, F i l j a k, 1951), and again only a few years ago (Š e b e č i ć and S l o v e n e c, 1990). Their significance is for the present more important from sedimentary, petroleum-geology and mineralogical than from

economic reasons. About 200 t of raw material was processed in so called "mailers" in Sinj up to 1951, and gave good quality oil. The quality the raw material of kerogenous rocks can also be estimated according to the upper thermal values. It has thus been determined that better quality material (from 2.500 to 4.800 kJ/kg) is largely linked to kerogenous occurrences 2 and 3, that is to stromatolitic carbonate rocks.

The kerogenous deposit Trlji in Istria was discovered during the French occupation of the peninsula, and it was mined by the Italians with test shafts of between 7 and 8 m in depth, between the two world wars. Research was resumed only 10 years ago (V u č k o v i ć and S r n i ć, 1983 and Š e b e č i ć et al, 1990) These kerogens are Cenomanian, partially stromatolitic, limestones 2 cm - 3 cm to 70 cm thick, in a limestone zone of 5 m thickness. A very variable pyrolized organic matter content has been determined (0.43% - 20.74%, $\bar{x}$=6,31%, from 12 samples) and a variable upper thermal value content (92kJ/kg-6338kJ/kg, $\bar{x}$=2143kJ/kg from seven samples).

In Rebići, 5.5 km south of Barban in Istria are Upper Cretaceous weakly kerogenous limestones with 0.19% to o.66% total organic matter ($\bar{x}$=0.34%, N=9), in places with a little bitumen. Pyrolisis of organic matter at 550^{0}C/10 min, by which the total organic matter content was determined, and pyrolisis of organic matter at 350^{0}C for 20 min, by which bitumen content was determined, was performed by chemical technician B. *Stipak.*

According to the tabular report of *Garapics* and *Pantz* 1804 (E r c e g, 1992) it was correctly concluded that existence of "tar" at depth would not repay the trouble of digging out the ore, but the name of the occurrence was incorrectly noted as Sebische instead of Rebische. For this reason this occurrence near Barban was forgotten, and was not noted on the Basic Geological Map, Labin Sheet (Š i k i ć et al, 1969). Yet the adit (Fig. 22) has remained preserved; it is assumed to be about 150-200 years old, with dimensions 5.5 m x 1.6 m x 1.85-1.05 m. In it there are Touron plate limestones with small kerogenized foraminfers. In the limestones there are kerogenous spots of 0.05 mm to 1mm in size, in the micrite basis of fossiliferous micrites (M-w) and biomicrites (w). Bitumen traces are contained in samples, alongside the fault. The organic-kerogenous matter is similar to coal, and is found mainly in the coating of fissures. In 1927 there was an unsuccessful attempt by the Italians to resume exploration by digging a trench.

New knowledge obtained from mining and geological exploration into bituminous and kerogenous deposits

On the basis of knowledge so far gained about the mining and geological exploration of bituminous rocks in Dinarid Croatia, author proposes that in the "Special criteria for the determination and categorization of the reserves of individual solid mineral raw materials" of the "Regulations about gathering data, the way of recording and determining the reserves of mineral raw materials and proving reserves" (N a r o d n e n o v i n e, 1992) bituminous should be distinguished from oil,that is kerogenous rocks.

It is possible to divide bituminous deposits in accord with the Regulations into three groups with respect to their various degrees of infiltration into and impregnation of rocks with hydrocarbons, that is, with bitumen. I place in the first group of deposits those with >300 x 10^3 t of bituminous rock mass, into the second group with from 100 - 300 x 10^3 tons and into the third those <100 x 10^3 tons of bituminous rock mass. Division into sub-groups is possible, but only after wide-ranging mining and geological investigation. For the exploration of bituminous rocks, proposed the following longest distance between drilling and mining exploratory works according to category of reserves (Table 2).

It is not yet defined how great the share of individual reserves in total reserves is, but author proposes, that A+B reserves constitute 60%-75% (with the proviso that A reserves constitute 2/3 of A+B reserves), and that C1 reserves make up 25%-40% of all reserves.

In order to calculate the potential reserves (C2, D1 and D2 categories) one first has to calculate the coefficient of productivity in detail of the explored region (balanced with A-C1 reserves), and the relation between the total bituminousness of the sufraces by which the categories of potential reserves are estiamted and the (total) bitiminousness of the surfaces which are explored in detail as a corrective factor for an estimation of reserves.

According to the present state of explotation, which is on the whole low, because it is mainly based on an estimation of potential reserves, most prospected or even partially investigated deposits would fall within the third group of deposits. The second group would include the Vinišće-Biskupija deposit, and it is assumed that Vrgorac-Paklina would come in the first group, insofar as the great reserves are confirmed by subsequent mining and geological explorations.

Depending on the quality of the raw material, that is mainly on the bitumen content, the use of bituminous rocks is possible. For road building a fairly high content of bitumen is useful >5%, that is, 6%-10% or 7.5%-12.5%, while the bitumen content for infill has practically no lower limit. I proposed a bitumen content of 1%-2% in rock as a conditional proven reserves limit, and >2% as a proven reserves quality.

I have placed kerogens, that is oil rocks, in three groups with the essential rider that if type 1 (sapropelic) or type 2 (sapropelic-humus) kerogens are found in them, these are oil shales, while if type 3 is found, humus kerogens, then these rocks should be called coaly shales.

In kerogenous shales, kerogen can be more or less uniform concentrated in the whole rock, that is, these are homogenous oil shales; these are rarely found in Croatia. Kerogen is most often found in laminated or thinly sheeted sediments alternating with similar but barren sediments with very little or no kerogen, and finally, in layered-lensed accumulations. I disinguish our kerogen deposits according to size; the first group is composed of deposits of 3 x 10^6 t of kerogenous rocks, the second of those of from 3 x 10^5 to3 x 10^6 tons of kerogenous rocks, and the third groups contains deposits of <3 x 10^5 tons of kerogenous rocks. The kerogenous deposits of Postak, it is supposed, could for example be pit into the first group, Vrdova- Golo Brdo into the second, and Braca-Brizi into the third. According to our understanding to date, only a small part, for example 1/10 of kerogenous rocks from deposits that have been studied could be used as sources of power (for example, the kerogen deposits in Vrelo Koreničko).

Whit respect to the largely low thermal value of the tested average samples of parts of the deposit of Mrsinj Grad in Vrelo Koreničko ($\bar{x}$=1986, kJ/kg from 52 samples) it has been established that the rocks investigated can be used only as a source of initial energy for the onset of combustion (1650 kJ/kg). For this reason our low energy kerogenous shales can be used only as filler in asphalt systems.

For the investigation of kerogenous rocks, I propose the following maximum distance between drilling and mining exploratory works according to reserve category (Table 3). These distances are quite close to the distances determined for the exploration of bituminous or oil rocks (N a r o d n e n o v i n e, 1992). For exploring lenticular kerogenous deposits, destances between drilling and exploratory mining works, it is appropriate to use those that are used for bituminous deposits. The same holds true for mixed bituminous-kerogenous deposits (Gornja Rošca and Novska-Paklenica).

During geological exploration and charting of occurrences of rocks enriched with organic matter (with bitumen and/or kerogen), the greatest geological risks exist during estimating the geological potential (C_2 or D) reserves, for there is a lack of mining and geological exploratory works. These risks can be reduced by investing in exploration. As well as geological there are considerable economic risks. The cost of industrial bitumen rises or falls with the changes in the price of oil on the market. That is why, before a decision about exploitation is made, a cost analysis should be made for obtaining 1 ton of natural bitumen from asphalt, and 1 ton of bitumen from oil, or perhaps the price of 1 ton of natural fillter with organic matter, and 1 ton of industrial filler of the same composition.

Further, account should be taken of exploitational risks. First, it has to be found out whether with previous criteria (N a r o d n e n o v i n e, 1992) we can with cartainty count upon the reserves that we wish to determine and secondly whether with the proposed new

criteria about the minimal distance between exploratory mining works (Tables 2 and 3 in this work) it is economically justifiable.

On the basis of mining and geological, and geophysical data about the thickness of bituminous occurrences or deposits, and the thickness of the outcrops I have approximately estimated the reserves of the most important Croatian occurrences and deposits. Most occurrences contain 5-10000 t of natural asphalt, and only a few deposits have reserves of >80000 tons (Table 4).

Among the most important deposits in Croatia are Paklina, near Vrgorac, Vinišće Biskupija, Primorski Dolac - Balovi, Donji Dolac, G. Rošca and others, where exploitation has been halted. Some deposits should be worked on in a more detailed way from mining and geological points of view, as for example in the Mosor bituminous zone (Donji Dolac - Okkruglice and Mišetin Dolac), and in the Biokovo bituminous zone (Kozica, Vranješi and Grljušići).

As far as the "oil shale" deposits are concerned, or kerogenous sediments, the most interesting are in Ruda, near Sinj, and Vrelo Koreničko (Zubovića and Milanovića Draga). In Ruda, underground exploration was halted, while in Vrelo Koreničko it was started, and stopped. Of those deposits that have been opened up and closed down, it would ve interesting to explore those on Brač (Brizi) and Dinara (Vrdovo), for they contain elevated organic matter contents, that is kerogen, and with them elevated thermal values of the raw material. It can be concluted about most of the occurrences that it would be irrational to explore them at present, for they contain mostly low organic matter contents. The biggest kerogenous deposit in Croatia, Poštak, also comes within this group. It is estimated that the geological reserves of the mentioned biggest deposits (Table 5), go up from 300000 to 2300000 tons, while smaller deposits (on Brač) have about 60000 tons.

Transforming resources into reserves

As well as finding new deposits of bituminous and kerogenous rocks, it is also important to transform the resources in some occurrences into reserves. It is not easy to find new deposits, and it is linked largely with mining and geological, organic chemical and technological investigations of the raw materials of some already well known and promising occurrences or for the discovery of entirely new occurrences, which is a much less frequent matter.

The transformation of resources into reserves happens in connection with very promising occurrences where conditional proven reserves have been determined, or where one-time abandoned deposits with lower quality raw material are reactivated for exploitation. The transformation itself is a dynamic process (S i n g h, 1984) and in most cases is associaded with new technologies for the application of material with a lower useful component content. This is the case for example with bituminous and kerogenous rocks and their applications in fillers in road building systems, and esepcially with kerogenous rocks (oil shales) in connection with their use as special oil lubricants (E n c i c l o p e d i a i t a l i a n a, 1949) or their combustion in fluidized layer such as low calorie coal and carboniferous sediments, or even for combusion in a Sterling motor (accorrding to the oral communication of Prof. *Abramović*). Furthermore, the waste heaps of coal and oil shales are interesting for the purposes of fertilization and also for being recultivated and being used for economic and other purposes. In oil and/or gas fields with existing drillings it is possible to bring about the de-gassing of drilled coal layers, or kerogenous sediments. Methane gas can also be obtained from mines where there is for example coal, or carboniferous sediments and so on.

Discussion and conclusions

It is well known that bituminous rocks (natural asphalt) and kerogenous rocks (or oil shales) are enriched with organic matter. In Croatia these are largely carbonate rocks: limestones and dolomites, with a smaller amount of sandstones, siltstones, shales, cherts and others. The soluble bitumen and/or insoluble kerogen content from which oil is obtained can vary considerably, which affects changes in the quality of the raw material and the size of the deposit. Depending on the bitumen and/or kerogen content in the total organic matter or in the rock the investigated rock can be categorized as bituminous, if it contains >50% bitumen in the total organic matter, or kerogenous if it contains >50% of kerogenous matter in the total organic matter. The following division can be made if account is taken of the existence of one or two hybrid rocks (Fig. 1), and practically a tripartite (as in this work) or four-part division can be made, as in the division of hybrid carbonate rocks which I published in 1983. In accord with this it is possibel to distinguish "kerogenous bitumenous rock" or "bituminous kerogenous rock". In accord with S c h m i t z' s division (1986) it is possible to divide organolites into: pure bitumen, bitumenides, bituminous rock, or pure kerogen, kerogenides, kerogenous rocks.

By mining and geological research into the bituminous and kerogenous deposits in Croatia, I have come to the understnding that it is necessary to use special criteria to evaluate bituminous and particulary kerogenous deposits, because one is similar to bauxite deposits, and the other to coal deposits. That is why I adopted the distances between exploratory works (Tabes 4 and 5) to Croatian reserves (A, B, C_1). As far as bituminous reserves are concerned, I distinguished three groups, with reserves $>300 \times 10^3$ t, 100-300 x 10^3 t, and $<100 \times 10^3$ t, and with kerogenous deposits another three grups of reserves, $>3 \times 10^6$ t, 3 x 10^5-10^6 t and $<3 \times 10^5$ t. For the exploration of bituminous-kerogenous and lenticular kerogenous deposits the same distances between drilling and exploratory mining works that are applicable in bituminous deposits are suitable. Before a decision about the exploration and exploitation of some old deposit is made, the exploitational and economic risks should be properly analyzed.

Since data are not available about the exploitation of natural bitumens in Croatia in the middle ages, all considerations about the possible amounts of pitch obtained in this period take on the character of more or less adequate hypotheses. I presume that bitumen was in fact obtained from deposits close to the sea like that in Vinišće, on the island of Brač (Pučišća and Škrip) and in the vicinity of the river Neretva (Paklina). Vinišće might have been a port for the construction or repair of boats, as is witnessed to by its suitable location between Šibenik and Split and by the remains of pillars in the sea in the Vinišće bay. Since ancient times natural bitumen or pitch has been recorded as being used for the hydroinsulation of ships and boats, in lubrication, in building, in defensive actions during the siege of cities, in sea battles with "Greek fire" and so on. Pitch could be used from one's own deposits, or imported, or perhaps tar could be used gained from the distillation of wood.

The history of the mining of bituminous or asphalt deposits in Croatia is more than 400 years long. According to M a t t h i o l i (1565) we can conclude that of the oldest deposits in Dalmatia is to be found in the vicinity of the mouth of the Neretva. It is necessary to emphasize that another very old deposit is found in Vinišće not far from the sea (now called Opatija), and in the hills (Biskupija), and also on Brač in Škrip and elsewhere. In Pannonian Croatia the oldset deposit of bitumen, or of oxidised oil, is noted in Peklenica in Međimurje. It was in the middle of the 19th century that intensive exploration for asphalt began in the Mosor region (Krivi Dolac), with exploration of asphalt in Vinišće having been renewed slightly earlier, in Opatija, when the first "factory" for asphalt processing was up. Asphalt production reached a peak at the end of the 19th century.

Mining of kerogenous deposits, or "bituminous ("oil") shales" earlier called "stone" or "fossil" "coal" was begun over 200 years ago at Smirča on Brač, for which the credit should be given to the Croatian explorer *J. Bilić (Billio)*, who played a large part in the exploration of Promina and Skradin coals. "Stone coal" from Brač was taken to Rijeka for the needs of the sugar refinery there. "Oil shales" were soon discovered in Istria too (Trlji), in the Sinj field, in Slivno (Kremena) and in the middle of the 19th century in Brač once again (Nerežišće, Splitska and Mirca). The most important period for oil shales in Croatia is connected with the beginning of their processing in Baljevac and Sinj at the beginning and in the middle of the 20th century.

There is a good deal of discussion of "oil shales" or, as it would be better to call them, kerogen sediments, particularly during the time of energy crunches or increased needs for power, in periods of world wars, economic and political blockades, new jumps in the

price of oil and gas on the world market, and when there are no new reserves of basic sources of energy. They are little used at the moment because shale derived oil cannot yet compete with cheaper petroleum. For this reason kerogen sediments, as an alternative source of energy, must be left to the future.

As mining requires financial investment for exploration, and a considerably greater investment to extract the raw material, many plans or inititated explorations were halted for neither in the past nor now have there been suitable investors, big capitalists like *Baron Rothschild* in the 19th century who went on with works that had previously been abandoned, as in Vinišće and Vrgorac, or began them himself, as was the case with the coal mines in Siverić and elsewhere. Another problem was that even if local people had had the capital, they did not have the required expertise to carry on large-scale works. The situation unfortunately has not greatly changed in the 20th century. As a rare example, we ought to mention the surveyor *A. Dešković* from Omiš (A d r i a t i c u s, 1905), who took upon himself the building of a hydroelectric power plant "Gubavica" (Kraljevac) at the falls the river Cetina in Zadvarje (1912), encouraged by French and Italian capital and experience with construction of the first such power station "Krka" on the river Krka (A. Šupuk and V. Meichsner, 1895 from G a r i b o v i ć and M o s e r, 1995) Dešković's aim was to use the energy obtained to build up the coal and asphalt industries of Dalmatia at the beginning of the 20th century.

In Croatia today not a single bituminous or kerogenous deposit is being exploited. With smallish interruptions for world wars or exploration, exploitation went on the longest in the region of Vrgorac in Paklina and in Vinišće in the deposits of Opatija and Biskupija. All the other deposits are smaller in size and have been explored and exploited for a shorter period of time. Exploration and mining was done in various separate phases, as social systems and needs changed. Among the Vrgorac deposits, Paklina was exploited right up to ≈1986. It is necessary to say that mining exploration was mainly of a prospecting nature, while only a few deposits had mining exploration done in detail, including the asphalts of Paklina, Škrip, Vinišće and Donji Dolac, and the oil shales of Ruda near Sinj, Vrelo Koreničko, and Baljevac. Geological opinions about the chronostratigraphic origin were given, about the position and the way in which the deposits appear, about estimates of reserves, the quality of the raw material, and exceptionally about the physical characteristics of the rock that contains organic matter. Occasionally there has been discussion about the genesis of the organic matter, and in more recent times about the petroleum geology features of rock in which organic matter has accumulated primarily or secondarily.

Only a few deposits have been covered in detail by mining and geological explorations: the bituminous deposits of the Trogir region - Vinišće-Biskupija and Ninčevića Lokva in Radošići one bituminous-kerogenous deposit from the Mosor region (Gornja Rošca, D. Dolac) and one from the Slavonian region (Paklenica near Novska). Since there were only preliminary chemical and physical-chemical analyses tests done on the bitumen and the rock mass only a brief view into the possibility of applications was obtained, including for filler for asphalt mixtures and such like; however, natural asphalt should be investigated with much more technological thoroughness to find a way of using it to the full.

Geological and mining exploration of kerogenous rocks, of the so called oil or bituminous shales, were begun only twenty years ago, for Vrelo Koreničko in the area of Lička Plješivica and for Dimići in Poštak, so that at the present time it is not possible to estimate the potentials of these raw materials in Croatia for possible use. The first explorations gave modest results to do with raw material quality, so that we can at the moment only recall that with the old technology (the "mailers"), probably from selected raw material, a certain quntity of crude oil was obtained in Ruda near Sinj. This may be connected whith the once highly valued healing properties of a preparation obtained from oil extracted from the ichtyol-shales of Baljevac, i.e. Plješivica.

On the basis of explorations made to date of the bituminous and kerogenous rocks of Dinarid Croatia and analytical data regarding their quality it can be concluded that in the Dinarids of Croatia almost 173 smaller and larger deposits have been registered. Of these, 42 belong to bituminous rocks, 20 to bituminous-kerogenous rocks, and 111 to kerogenous rocks. According to raw material quality, selection has been made among the localities mentioned, and about 30 deposits distinguished, while most localities have been classified as occurrences.

Of these 30 deposits, 15 are bituminous, 13 kerogenous, and 2 bituminous-kerogenous. It can be assumed that about one half of these 30 deposits might be interesting for future mining and geological exploration. The high ratio of occurrences to deposits (6:1) in both bituminous and kerogenous rocks shows high variable the quality of the rocks tested is. Bituminous deposits in Croatia feature a variable bitumen concentration, with bitumen bodies of small dimensions. For this reason the exploitation of bituminous bodies should be organized in such a way as to encompass a number of similar deposits in a single area. The required bitumen content can be achieved by mixing materials with various bitumen contents, and if necessary by addition of industrially prepared bitumen. Further, it is necessary to bear in mind that only exploitation which is not expensive, or burdened by heavy transport costs to the place of use, is justifiable. This goes also for the low-energy "oil shales" which could be used in the brick industry and the cement industry, as an energetic and raw material supplement.

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